UNIVERSITY OF ALBERTA

THE BIOLOGY OF THE ARCTIC GRAYLING, *THYMALLUS ARCTICUS* (PALLAS), IN GREAT SLAVE LAKE

by

© FRANK GEORGE BISHOP

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF ZOOLOGY

EDMONTON, ALBERTA

OCTOBER, 1967

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "The Biology of the Arctic Grayling, *Thymallus arcticus* (Pallas), in Great Slave Lake", submitted by Frank George Bishop in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The Arctic grayling, *Thymallus arcticus* (Pallas), was studied in western (Mackenzie River) and eastern (Stark River) regions of Great Slave Lake during 1965 and 1966.

Grayling from the East were slightly smaller in length and weight than grayling of the same age group from the West. Both East and West grayling grew at similar rates, with the greatest increments occurring in the 0-5 age groups. Western grayling apparently grew faster than those in the East in the 0-1 age groups. Male grayling were only slightly larger than females in age groups 3 to 12, in both locations. Results from the condition factor k showed that grayling from the West were plumper than grayling from the East.

Taxonomic measurements indicated that there are likely no racial differences between the East and West populations of grayling, although there are slight variations. There are significant sexual differences in the lengths of the pelvic fins and in the dorsal fin heights.

Overall sex ratios from the East were 1:1. In the West the ratio was 1.8 to 1 in favor of the males. A theory is proposed that females and younger grayling inhabit different areas than do the larger males. The sex ratio of the spawning run was 1.3 males to 1 female.

In the West 95% of the grayling were mature at age 6, and not until age 7 were about 95% of the eastern grayling mature. The 6 to 9 age groups made up 93.5% of the spawning run.

Spawning time of the grayling occurred in May in Providence Creek. The main spawning activity took place from noon until dusk and was apparently governed by the temperature of the water. Artificially fertilized eggs hatched in 13.7 days in an average water temperature of 9.1 C.

Grayling fry ate mainly Cladocera and small Ephemeroptera nymphs. Larger grayling from the western location fed mainly on aquatic insects, with the Trichoptera being the single most important food item. The diet of the eastern grayling was more varied with aquatic and terrestrial insects and fish being the most important items.

Observations showed that the grayling has few competitors, predators or parasites in Great Slave Lake. Angling pressure in the lake is very slight.

It was recommended that no changes be made in the existing regulations which govern fishing in Great Slave Lake because the data obtained in this study indicate that grayling populations are in satisfactory condition. However, it was also recommended that a study be made at a later date to determine if any important changes have occurred in these populations. At such time, the regulations should be reviewed and changed, if necessary.

ACKNOWLEDGEMENTS

I would like to express my appreciation to the Fisheries Research Board of Canada, for the opportunity to undertake this study and for all the assistance that they provided.

I would particularly like to express my thanks to Dr. J. R. Nursall, Head of the Department of Zoology, University of Alberta, for his guidance and supervision in this study, and for critically reviewing the manuscript. Likewise, I would like to thank Mr. J. J. Keleher, Biologist in charge of Great Slave Lake studies, F.R.B.C., for his direction and suggestions in the study and for the assistance that he and his staff provided with the I.B.M. data.

During the two summers of field work, numerous arduous tasks had to be performed which could only have been accomplished through the cooperation of a number of people. I am sincerely grateful to Mr. Con Haight and Mr. Bill Weselowski of F.R.B.C., Hay River, who taught me the intricacies of gill netting, brought supplies to our camps, and who provided many helpful suggestions throughout the study and without whose help the study would have been very difficult. I would also like to express my sincerest thanks to my assistants, Dave Buchwald, John Little, and Bill Bond, for their enthusiastic interest and cooperation in the field.

I am indebted to T. E. McIntosh, C. G. Morgan and D. G. Barry of Computing Sciences, University of Alberta, Edmonton, for their help in programming the computer data.

My sincere thanks are due to the numerous persons who identified specimens for me: Dr. H. F. Clifford, Dr. D. D. Anthony, D. M. Rosenberg, D. J. Larsen, T. L. Erwin, A. P. Nimmo, R. E. Leech and R. B. Podesta. I would like to thank Dr. F. M. Atton for checking the ages of grayling scales for me.

My thanks to Mr. and Mrs. J. Bricker and their son Drew of Frontier Fishing Lodge, for their kindness and assistance they showed me while we were camped at Snowdrift.

I would like to acknowledge the assistance given to me by Morley Pinsent, Mike Robertson and Graham Daborn, for their many helpful suggestions and critical analysis of this study.

Finally, I would like to express my deepest thanks to my wife, Mary Anne, who spent many long hours on the calculator and typewriter and whose assistance helped me abundantly.

The fisherman is a worthy man,
Not given to misprision,
But he washes the scales from off his hands
And not from off his vision.
He may have won a master's degree
From M.I.T. or Fordham,
But he can't perceive that one man's fish
Is another fellow's boredom.

From: My Mind is Reeling
By Ogden Nash.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

The Arctic grayling, Thymallus arcticus (Pallas), is rapidly becoming one of the most popular game fish of Great Slave Lake because it is relatively easy to catch, exists in large numbers and usually puts up a good fight when caught on light tackle.

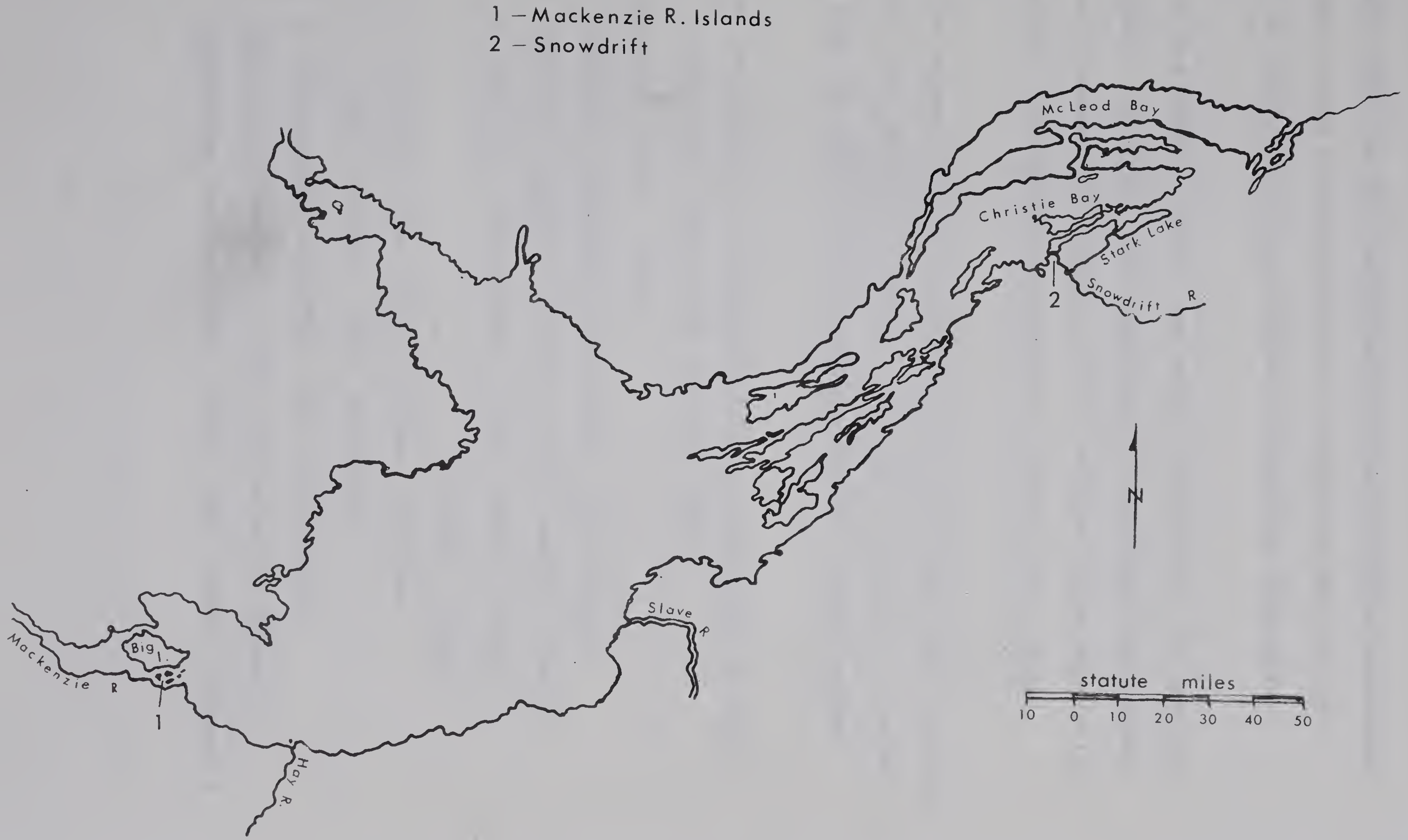
Until recently, not much was known about the ecology and life-history of the grayling. Interest in the species has recently developed because of concern over the decrease in size and numbers of grayling in certain regions of its range (Wojcik, 1955; Vincent, 1963).

Owing to the fact that Great Slave Lake is rapidly becoming important as an angling area, this study was initiated by the Fisheries Research Board of Canada with the purpose of investigating the biology of the Arctic grayling in this region before the populations of grayling were affected by the increasing numbers of anglers.

Two main locations were picked as study sites (Fig. 1): the Mackenzie River area in the western part of Great Slave Lake and the Stark River area in the eastern part of the lake. Both areas were known to support large populations of grayling. The study was carried out for two summers, with roughly equal time being spent at each location.

In North America, the principal range of the Arctic grayling is found to be in the Arctic Ocean drainages, in the Yukon River and its tributaries, in the Pacific Coast drainages in the headwaters of the Alaska and Stikine Rivers and east to the western shores of the Hudson Bay. The

Figure 1. Map of Great Slave Lake showing two main locations of study.


1 — Mackenzie R. Islands
2 — Snowdrift
McLeod Bay
Christie Bay
Stark Lake
Snowdrift R
2
N
Slave R
Big I.
Mackenzie R
1
Hay R.
statute miles
10 0 10 20 30 40 50

southern limit is the headwaters of the drainages concerned, and south along the west shore of the Hudson Bay to just north of the Nelson River system in Manitoba (Walters, 1955).

In the United States two relict populations of grayling are known. Of these, the population in Michigan has become extinct (Creaser and Creaser, 1935) and the other population, in Montana, has declined sharply in recent years (Kruse, 1959).

The purpose of this study was to investigate the ecology, behavior and general biology of the Arctic grayling in Great Slave Lake in order to gain information for future management.

The following is a classification of graylings as they are now recognized (taken from Vincent, 1963):

Thymallus Cuvier, 1829

T. thymallus thymallus (Linnaeus), 1758, Europe

T. arcticus arcticus (Pallas), 1776, Western Siberia

T. a. signifer (Richardson), 1823, Eastern Siberia, Alaska, Canada

T. a. tricolor Cope, 1865, Montana, Michigan

T. a. grubei Dybowski, 1869, Amur River

T. a. baicalensis Dybowski, 1874, Lake Baikal

T. brevirostris Kessler, 1879, Northwestern Mongolia

T. nigrescens Dorogostajkij, 1923, Lake Kosogal, Mongolia

II. PHYSICAL AND LIMNOLOGICAL FEATURES OF GREAT SLAVE LAKE

1. General Description

The physical and biological characteristics of Great Slave Lake have been described by Rawson (1950a, 1951, 1953 and 1956). Only certain aspects concerned with this study will be mentioned here.

Great Slave Lake lies in the Northwest Territories and is located at about latitude 62°N, longitude 114°W. It is the fifth largest lake in North America, having an area of 10,430 square miles. The deepest part of the lake is located in Christie Bay where a sounding of 614 meters (2,075 feet) has been made.

The edge of the Precambrian Shield runs through the middle of Great Slave Lake, thereby dividing the lake into two contrasting halves. The area to the west of the Precambrian Shield's edge contains low-lying regular shores, very few islands and the water is relatively shallow with a maximum of 153 meters (500 feet). In contrast, the northeastern part of the lake has a very irregular shoreline with many thousands of islands occupying nearly 30 per cent of the East Arm. It is in this area that the deepest soundings have been made. The mean depth of the larger bays and inlets in the East Arm is about 150-200 meters (492- 656 feet).

2. Fish in Great Slave Lake

There are 26 species of fish in the lake (Keleher, 1964). Commercially the most important fish are the lake trout

Salvelinus namaycush (Walbaum) and the lake whitefish, *Coregonus clupeaformis* (Mitchill). These make up approximately 95 per cent of the commercial catch (Kennedy, 1954).

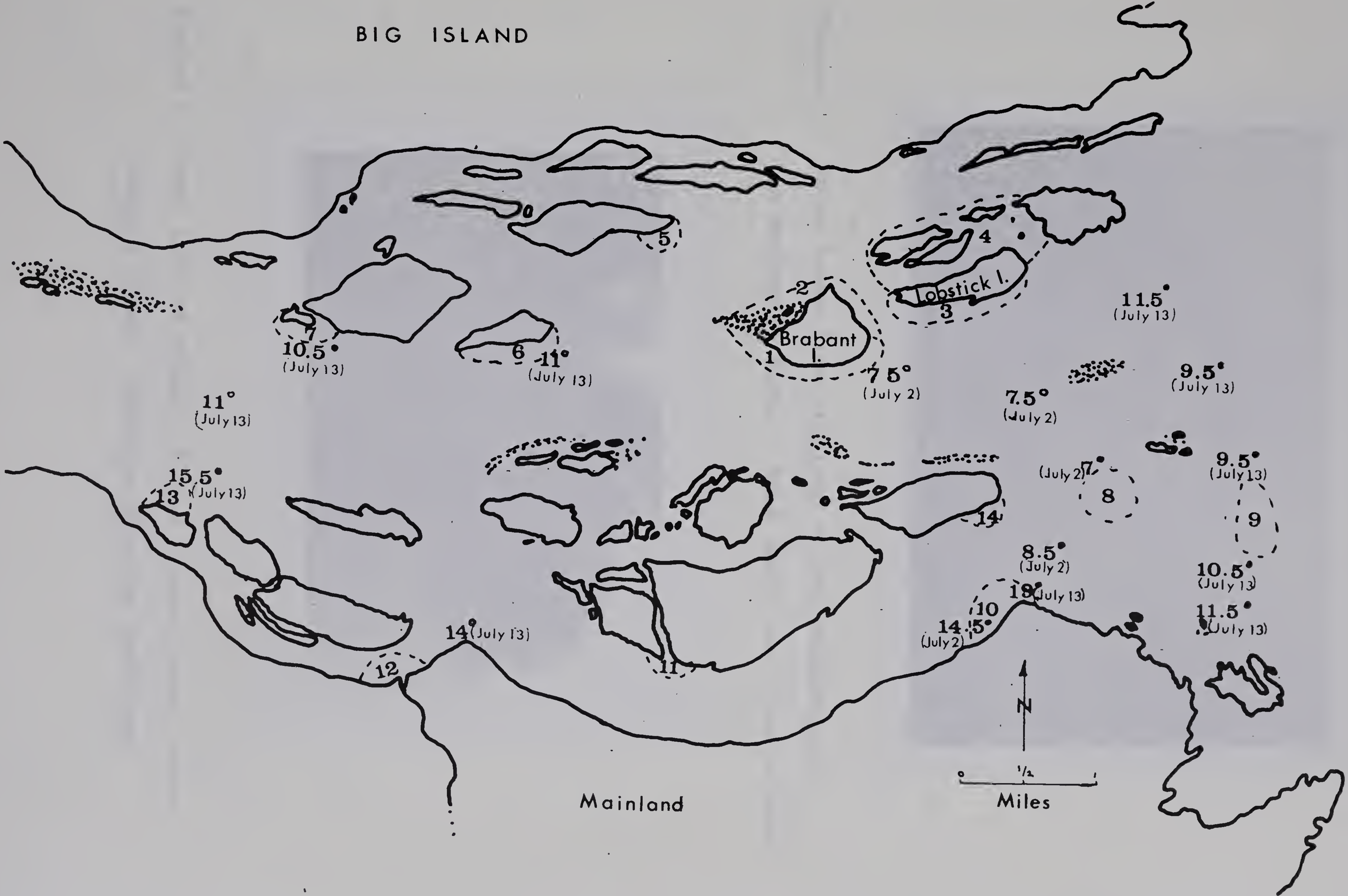
The important sports fish in the lake are the lake trout, Arctic grayling, northern pike (*Esox lucius* Linnaeus) and yellow walleye (*Stizostedion vitreum* (Mitchill)) (Keleher, 1966). The N.A. record Arctic grayling was caught in Great Slave Lake in August, 1959. It weighed 5 pounds (Keleher, 1961).

3. Description of Study Areas

The main location in the western part of the lake was situated about Brabant Island (61°04'N; 116°38'W) in the headwaters of the Mackenzie River (Fig. 2). This territory is found about 30 miles west of the town of Hay River, N.W.T. The river in this area is dotted with small, low-lying islands which are covered with spruce and dense brush and sphagnum (Figs. 3 and 4). The Mackenzie River at this locality is wide, (about 3 1/2 miles from southern shore of the river to the southern shore of Big Island) and shallow (mean depth about 5 feet).

According to Rawson (1950 a) the Mackenzie River usually becomes free of ice between May 15 and May 24. It opened during this period in 1965 and 1966. The ice from the main lake does not leave until about the middle of June, so it is quite late before the Mackenzie River is safe to navigate. Freeze-up in the fall occurs in the main part of the lake between December 15 to January 1. The ice usually reaches

Figure 2. Map of the main western location, located at the headwaters of the Mackenzie River, showing stations fished during study, and typical water temperatures.



BIG ISLAND
Brabant I.
Lobstick I.
Mainland
Miles
N
11.5° (July 13)
9.5° (July 13)
7.5° (July 2)
7 5° (July 2)
11° (July 13)
10.5° (July 13)
11° (July 13)
15.5° (July 13)
14° (July 13)
14.5° (July 2)
18° (July 13)
8.5° (July 2)
7° (July 2)
9.5° (July 13)
10.5° (July 13)
11.5° (July 13)
1
2
3
4
5
6
7
8
9
10
11
12
13
14

Figure 3. Photo taken from airplane of the headwaters of the Mackenzie River. Note small low-lying islands.

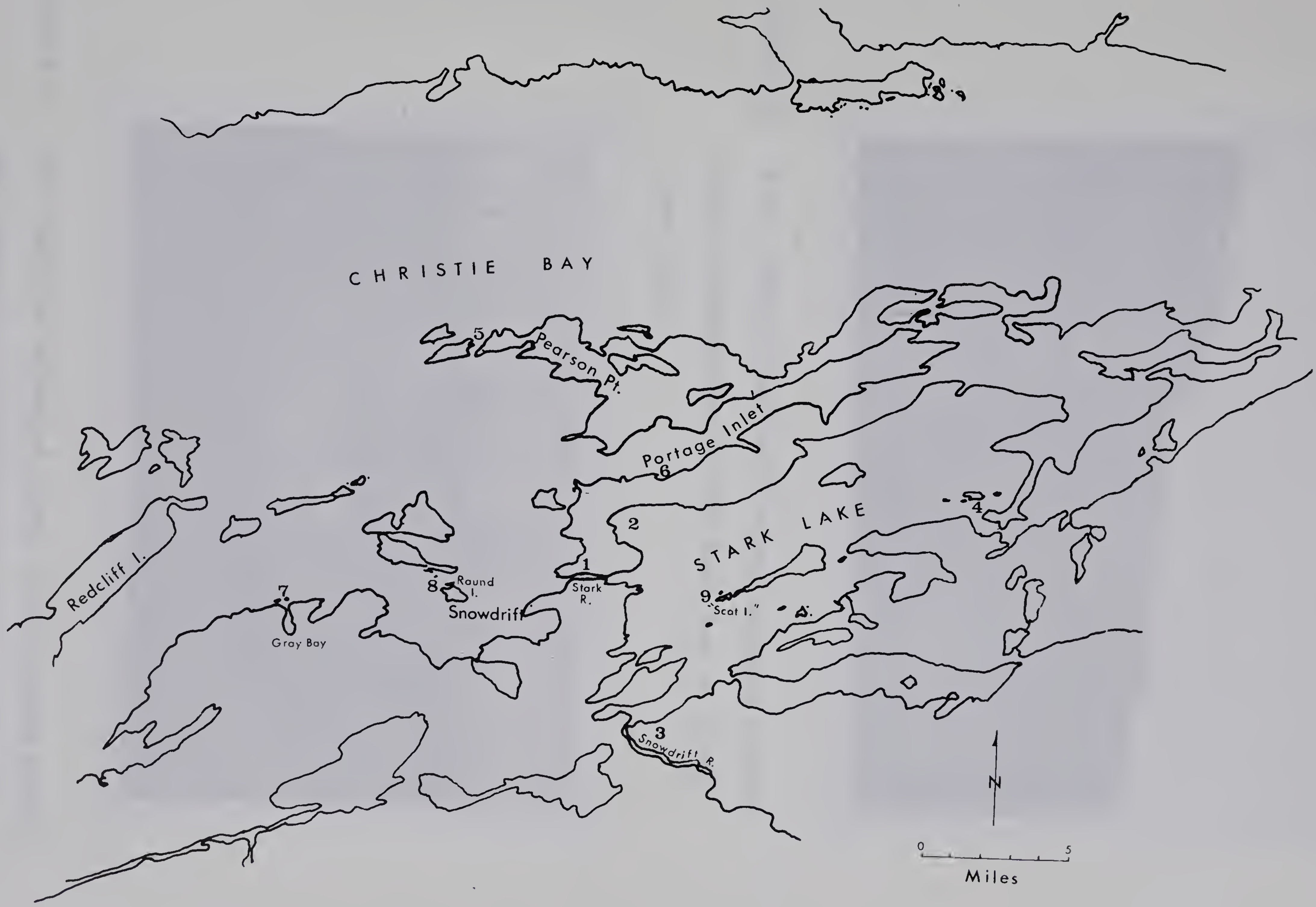
Figure 4. West side of Brabant Island showing dense, overhanging brush. Favorite grayling locations.

a maximum thickness of 5 or 6 feet about March.

The main location in the eastern part of the lake was the Stark River (sometimes called Snowdrift River), located about one mile east of the small Indian village of Snowdrift, N.W.T. (62°23'N; 110°47'W) (Fig. 5). The village is about 200 air-miles N.E. of Hay River. In this end of the lake the rugged topography, characteristic of the Canadian Shield, is a sharp contrast to the marshy, low Mackenzie lowlands to the west. The Precambrian formations of granite and gneiss rise 200 feet or more in the eastern part of the lake and there are many small and scattered lakes in the surrounding area (Fig. 6). The dominant vegetation is white spruce associated with white birch and numerous lichens (Fig. 7).

The Stark River is a cold, fast-flowing river about 1 1/2 miles in length that flows from Stark Lake into Great Slave Lake through a relatively straight channel (Fig. 8). The width of the river is approximately 50 yards and it has an average depth of about 10 feet. There are two sets of rapids, the one nearest the mouth being known as the First Rapids and those further upstream called the Second Rapids. The water flowing over the rapids is very shallow and great care had to be exercised in traversing the river. In the middle of the Second Rapids is a pool about 20 feet in depth. The Stark River does not freeze over in all places in the winter, the areas around the rapids remaining open (Mr. P. Jackson, Hudson Bay Manager, Snowdrift, pers. comm., 1966).

Figure 5. Map of the main eastern location, situated in the East part of Great Slave Lake, showing stations fished during study.

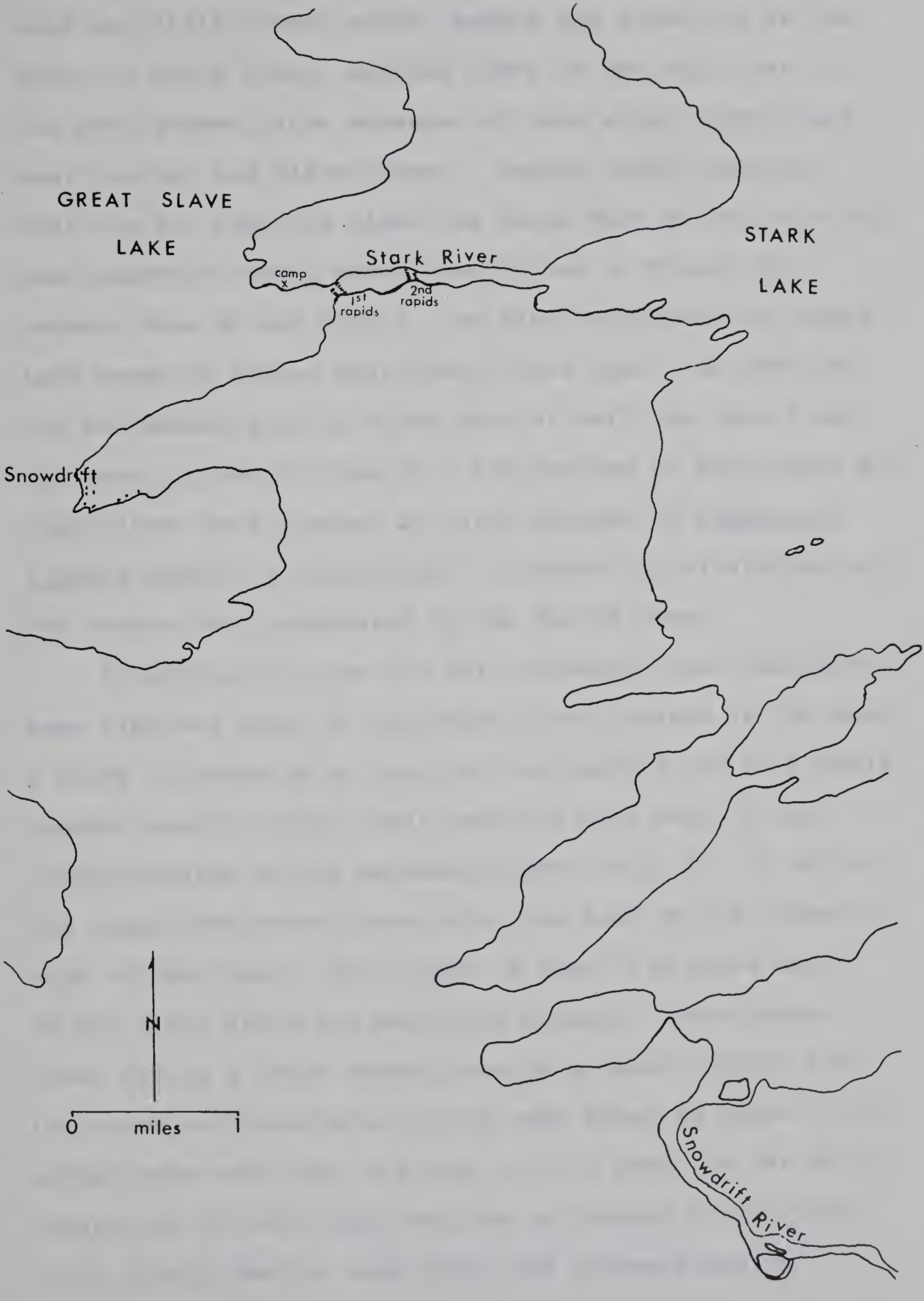


CHRISTIE BAY
5
Pearson Pt.
Portage Inlet
6
2
1
Stark R.
STARK LAKE
4
9
"Scat I."
3
Snowdrift R.
8
Round I.
Snowdrift
7
Gray Bay
Redcliff I.
N
0
5
Miles

Figure 6. N.W. side of Redcliff Island showing typical rugged appearance of the East Arm of Great Slave Lake.

Figure 7. Our campsite situated close to the Stark River, near Snowdrift, showing heavy spruce forest in background.

Figure 8. Map of the Stark River area.


GREAT SLAVE
LAKE
STARK
LAKE
Stark River
camp
x
1st
rapids
2nd
rapids
Snowdrift
N
0 miles 1
Snowdrift River

On June 1, 1966, the eastern part of Great Slave Lake was still frozen solid, except for a portion at the mouth of Stark River, whereas parts of the main lake in the west showed large expanses of open water, especially near the Hay and Slave rivers. Rawson (1950) reported that the ice does not clear the south part of Christie Bay near Snowdrift until about June 20 and in McLeod Bay between June 24 and July 1. He also indicated that Stark Lake warms up faster than Great Slave Lake. In 1966 the ice was breaking up in Stark Lake as early as June 3 and was mostly clear by June 20. The bottoms of Stark Lake and Stark River were covered by large patches of *Leptomitus lacteus* Agardh, a fungus that is common in polluted waters. The fungus had disappeared by the end of June.

In addition to the two main locations just described, some time was spent at two other sites located in the west. A study of spawning by grayling was carried out at a small, unnamed creek located about one-half mile west of the ferry crossing on the Mackenzie River (Fig. 9). I called the creek Providence Creek after the town on the opposite side of the river. This creek is about 139 miles west of Hay River along the Mackenzie Highway. Providence Creek drains a large swampy area in a spruce forest and the water is characteristically very brown in color. The stream runs very fast and deep (3 to 4 feet) in the early spring but by late June its flow is reduced to a trickle. It is likely that in some years the stream dries up completely.

Figure 9. Map of Providence Creek and Kakisa River locations.


Lake
470
MERIDIAN ISLAND
512
Falls
Fort Providence
OP TP
RIVER
Ferry
Providence Cr.
500
560
Winter Road
SIXTH MERIDIAN
810
Burnt Pt
Beaver Lake
36th Base Line
Deep Bay
North Channel
BIG ISLAND
GREAT L
Beacon Pt
Pte Desmarais
630
535
Boulogne
61°
RIVER
KAKISA
Lady Evelyn Falls 48
KAKISA LAKE
730
Foetus Lake
Two Island Lake
830
N
0 5 10
miles

The last location studied was at Lady Evelyn Falls (height 46 feet) on the Kakisa River. The river is located about 86 miles from Hay River on the Mackenzie Highway (Fig. 9). The location is a very popular camping and picnic site and many people come in the spring to catch fish (Fig. 10). The Kakisa River is usually the first river to flow in the spring in this area. In 1966 it opened up on April 30.

The allotment of time and the numbers of fish caught at each location was as follows:

		Angling	Gill Net
1965	Kakisa River, May 22 - June 9	57	0
	Brabant Island, June 19 - July 31	272	171
	Stark River, August 3 - Sept. 11	657	301
1966	Providence Creek, May 4 - May 28	64	99
	Stark River, June 1 - July 5	160	309
	Brabant Island, July 6-9; 14-29	273	0
	Total	1483	880

Figure 10. Lady Evelyn Falls on the Kakisa River.

III. MATERIALS AND METHODS

Data on 2628 grayling were collected in the two-year study period. Of this total, 880 grayling were taken by gill-netting, 1483 grayling were taken by angling, and 76 more were taken by various other methods such as seining, dip-netting and electro-shocking. A further 189 specimens were taken as part of a creel census carried out in 1965 at Kakisa River and the Mackenzie River.

The following specific areas around Great Slave Lake were investigated during the study: West - Kaksia River, Providence Creek, Brabant Island area; East - Stark River, Stark Lake, Snowdrift River, Great Slave Lake proper (Pearson Point, Portage Inlet, Redcliff Islands).

Angling methods consisted of fly fishing, spin casting and more rarely bait casting. Gill nets used in the study were of four sizes. The stretched measure of each is as follows: 2 1/2 inch (100 meshes in depth), 3 inch (40 meshes in depth), 4 inch (30 meshes in depth), and 5 inch (24 meshes in depth). The nets were made of 210/3 nylon. They were in lengths of 50 yards. They were usually set singly close to shore but were sometimes set in gangs of 2 to 4 nets.

The procedure adopted in recording the data was as set out in the Manual for Great Slave Lake Field Personnel (Keleher, 1964). A record was kept of all fish caught according to species, size, depth and set of mesh size. Weights were taken for all fish caught. Some other species

of fish were treated in the same manner as the grayling. All grayling were examined as follows:

1. Scales were taken from an area on the left side of the fish above the lateral line and in front of the dorsal fin.
2. The fork length was measured (in mm).
3. The girth was measured (in mm).
4. The weight was measured to the nearest tenth of an ounce.
5. The sex and sex condition were determined.
6. Any parasite or defect was collected or noted.

All the measurements taken on the fish were coded according to the method used by Fisheries Research Board of Canada (Keleher, 1964) for future I.B.M. analysis.

About 150 specimens, including equal numbers of males and females from each location, were fixed in 10% formalin and later removed from this solution, washed in water and preserved in 50% isopropyl alcohol. Stomachs were removed from approximately every fifth fish for content analysis. In 1965 the stomachs were put in plastic bags with 10% formalin and later washed and transferred to 50% isopropyl alcohol. In 1966 the contents of the stomachs were determined while fresh, in the field. Specimens from the stomachs were preserved in 70% ethyl alcohol. The stomach contents were divided into groups of organisms and each group measured volumetrically. Organisms were identified to the family level and further where possible.

The age of all grayling caught was determined by an examination of the scales using a low-power binocular microscope. Growth data from the scale envelopes were punched onto I.B.M. data cards at the F.R.B.C. station in Winnipeg. Further changes and corrections were made at the University of Alberta Computing Center in Edmonton. Data on growth, age, sex, and gear statistics were computed at the Edmonton center on the 7040 I.B.M. machine.

Observations on spawning behavior and behavior in general were made using a glass-bottomed viewing box. The measurements of the box were 15" x 15 1/2" x 18 1/4". Polaroid glasses were also used but without too much success.

Egg counts of spawning females were measured by the volumetric method and checked by actual counts of the eggs in the ovaries.

Morphometric measurements were made on 80 preserved individual fish, 40 from the East and 40 from the West (20 males and 20 females in each group). The method used was described in Hubbs and Lagler (1958).

IV. GILL NET RESULTS

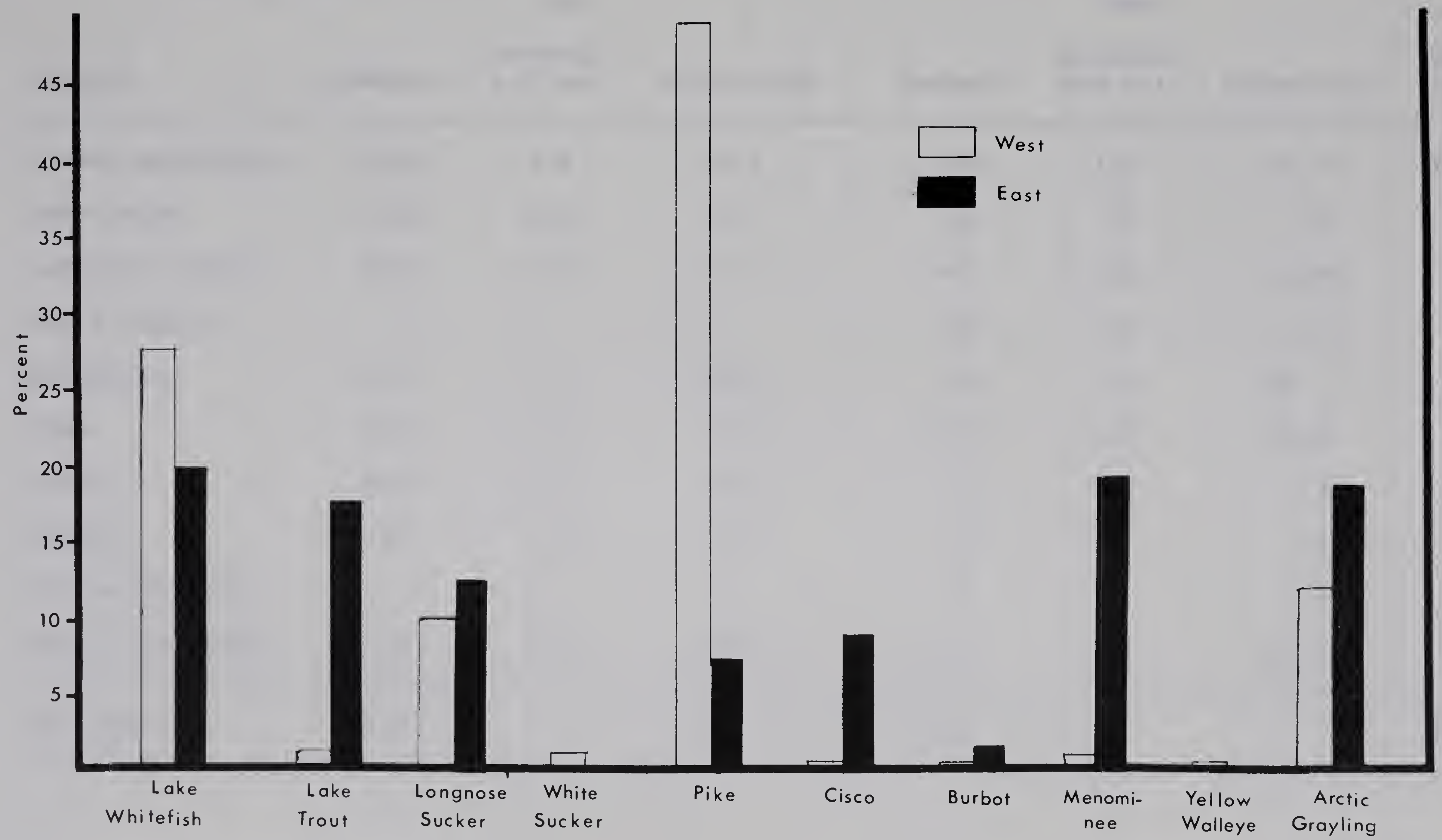
1. Percentage of Total Catch of Various Species of Fish

Certain interesting information was gained from the catch statistics from the gill netting program. It should be noted here that a greater netting "effort" was made in the East than in the West so it can be expected that greater numbers of fish will be caught in the East than in the West if the fish are equally abundant in both ends of the lake. One hundred and ninety-one nets of 50 yard gangs were set for one night each in the East. In the West there were 120 nets of 50 yard gangs set for one night each. The sets were all in shallow water, mostly in water one to twelve feet deep, but in certain cases, down to depths of 50 feet.

As Figure 11 and Table I show, a higher percentage of grayling were caught in the Eastern part of the lake than in the West. One factor that limited the number of grayling being caught in the West and the "mossing-up" of the nets. It was very hard to keep the nets clean of algae and other floating plant debris in the West, especially as the summer progressed and the water got warmer. Often nets had to be dried out completely after only one night's set owing to the amount of plant material caught in thenets. The grayling particularly seemed to resist getting caught in a dirty net. Observations showed that a dirty net tied to a clean net caught very few grayling while the clean net caught many more fish. The water in the eastern part of the lake was generally much cleaner. One exception was

Figure 11. Gill net results, 1965 and 1966. Expressed as percentages of total catch.

(Does not include Providence Creek fish.)



Percent
45
40
35
30
25
20
15
10
5
West
East
Lake Whitefish
Lake Trout
Longnose Sucker
White Sucker
Pike
Cisco
Burbot
Menominee
Yellow Walleye
Arctic Grayling

Table I. Total numbers, averages per net, and percentages of fish in the 1965 and 1966 gill net catches.

	East			West			
Species	Numbers	Average per net	Percentage	Numbers	Average per net	Percentage	Total catch
Common whitefish	652	3.4	19.1	389	3.2	27.2	1041
Lake trout	535	2.8	15.7	12	.1	.8	547
Longnose sucker	406	2.1	11.9	140	1.2	9.8	546
White sucker	1	-	-	14	.1	1.0	15
Menominee	632	3.3	18.6	13	.1	19	645
Pike	237	1.2	6.9	679	5.7	47.5	916
Cisco	287	1.5	8.4	5	-	.3	292
Burbot	41	.2	1.2	5	-	.3	46
Yellow walleye	-	-	-	2	-	.1	2
Arctic grayling	612	3.2	18.0	171	1.4	11.9	783
All species	3403			1430			4833

in the early spring (June) when masses of the fungus Leptomitus lacteus floated down the Stark River and fouled the nets. This was only serious for about one week.

With the exception of whitefish it can be seen that the fish populations of the East vary considerably from those of the West (Fig. 11).

Although whitefish are common in both ends of the lake, lake trout were decidedly more numerous in the colder eastern end of the lake. The trout that were taken in the West were only caught for a one week period while the water was relatively cool, in July. There appeared to be slightly more longnose suckers in the East than in the West. More white suckers were caught in the West. The white suckers and most of the longnose suckers caught in the West were taken during their spawning period in June. The pike show a definite preference for the warmer waters of the West. More ciscoes were caught in the East than in the West, but this was probably due to the fact that much of the netting in the East was done in the lake proper which would be more suitable for ciscoes than the river habitat of the Mackenzie River. The same reasoning would account for the abundance of burbot and menominee in the East over the West. The only walleye caught were taken in the warmer western waters.

2. Catch in Different Mesh Sizes

Tables II and III show the breakdown of the numbers of fish caught in the different mesh sizes. It is apparent that the 3-inch and 4-inch nets were responsible for catching

Table II. Numbers of fish of various species caught in different mesh sizes in 191 sets of 50 yard gangs in the East, 1965 and 1966.

Species	2 1/2" (5 nets)	3" (64 nets)	4" (63 nets)	5" (59 nets)	Total
Common whitefish	18	235	210	189	652
Lake trout	10	191	158	176	535
Longnose sucker	7	143	191	65	406
White sucker	-	1	-	-	1
Menominee	16	463	135	18	632
Pike	1	87	82	67	237
Cisco	20	196	24	47	287
Burbot	-	16	21	4	41
Arctic grayling	27	310	218	57	612
Total number	99	1642	1039	623	3403
Per cent	2.9	48.3	30.5	18.3	100.0

Table III. Numbers of fish of various species caught in different mesh sizes in 120 sets of 50 yard gangs in the West, 1965 and 1966.

Species	3" (27 nets)	4" (43 nets)	5" (50 nets)	Total
Common whitefish	55	196	138	389
Lake trout	-	8	4	12
Longnose sucker	5	35	100	140
White sucker	-	-	14	14
Menominee	3	6	4	13
Pike	196	338	145	679
Cisco	3	1	1	5
Burbot	-	1	4	5
Yellow walleye	-	1	1	2
Arctic grayling	8	85	78	171
Total number	270	671	489	1430
Per cent	18.9	46.9	34.2	100.0

most of the grayling in the East (Table II). These nets were most used. The low numbers shown for the 2 1/2-inch net is mainly due to the fact that it was only used sparingly (5 nets). Considering all the species of fish caught, it can be seen that the 3-inch and 4-inch nets caught 48.3 and 30.5 per cent of the catch respectively in the East. The remainder of the catch was in the 5-inch net (18.3 per cent) and the 2 1/2-inch net with 2.9 per cent.

In the West, the 4-inch and 5-inch nets were used the most, and not surprisingly, they caught the most grayling (Table III). Again the reason for the low numbers of grayling in the 3-inch net lies partly in the reason that it was not used as much as the others. More important, however, is the fact that the 3-inch net seemed to be very susceptible to "mossing-up". For this reason the 2 1/2-inch net was not used at all in the West. The 4-inch net caught 46.9 per cent of all species of fish taken in the West. This was followed by the 5-inch net with 34.2 per cent and the 3-inch net with 18.9 per cent of the total western catch.

3. Gear Selection Bias

The fact that a bias existed between the two main methods of collecting grayling is evident from Table IV. The average length of the grayling caught by gill nets, was larger in all mesh sizes except for the 2 1/2-inch mesh net, than the average size of grayling caught by angling. In each case, in the East and in the West, the 3-inch, 4-inch

Table IV. Gear selection bias and efficiency of gill nets.

		Number of grayling*	Mean Length (cm)	Number of yards set	Number of grayling per yard
Angling	East	816	337		
	West	841	389		
	Total	1657	364		
Gill Nets					
2 1/2"	East	27	320	250	.1
	West	none set	-	-	-
	Total	27	320		
3"	East	231	384	3200	.07
	West	6	413	1350	.004
	Total	237	384		
4"	East	193	419	3150	.06
	West	71	438	2150	.03
	Total	264	424		
5"	East	44	437	2950	.01
	West	194	425	2500	.08
	Total	238	428		

* includes Providence Creek fish. Excludes "Gray Bay" fish.

and 5-inch gill nets caught larger grayling than did angling.

Looking just at the gill net results in Table IV it can be seen that the grayling caught in each respective mesh size were larger in the West than in the East except for the 5-inch net where the fish from the East were slightly larger than those from the West. This may be due to small sample size of the 5-inch net in the East.

When the number of grayling caught in gill nets is divided by the yards of net used, some idea of the efficiency of each net size may be gained (Table IV). It is interesting to note that the 2 1/2-inch net is far superior to all the other mesh sizes by taking .1 grayling per yard. The worst net results was with the 3-inch mesh net in the West where only .004 grayling per yard were caught. It would appear that in the East the best nets for catching grayling would be 2 1/2-inch or 3-inch mesh nets. In the West, the best results would be had using 4-inch and 5-inch mesh nets.

V. DESCRIPTION AND GROWTH OF THE GRAYLING

1. Morphological Mesurements

a. Introduction

Measurements and counts were made to determine if there were any differences between males and females, and between grayling from the West and grayling from the East.

Morphological measurements were taken from 80 grayling: 20 males and 20 females from Stark River; 20 males and 20 females from Mackenzie River. The sample was composed of fish caught in 1965 and 1966. No size or age group was selected, although all the fish were sexually mature. All fish measured had been fixed in formalin and later transferred to 50% isopropanol.

Measurements were made according to the methods of Hubbs and Lagler (1947) (Fig. 12). The membrane on the opercular plate was included in the head length measurement. The dorsal fin height was measured from the posterior base of the fin to the tip of the fin when it was pressed down flat along the back of the fish. The t-test was used to measure the significance of differences between the East and West populations in various measurements.

Body dimension measurements were plotted as logarithms of the size of each body part against the logarithm of the standard length of the fish. The relative growth curve of each body part was plotted on log-log graph paper rather than by calculating the actual logarithms. Data concerning variation in

the 15 body parts are shown in Figs. 13-16. Crosses and dashed lines denote Stark River grayling; open circles and solid lines denote the Mackenzie River grayling. Lines were fitted by eye. Not all points are shown, in some cases, as points were too close to one another to be distinguished.

Explanation of abbreviations used in figures and appendix:

AB - anal fin base; AL - anal fin length; AR - anal fin rays; BD - body depth; CPD - caudal peduncle depth; CPL - caudal peduncle length; DB - dorsal fin base; DH - dorsal fin height; DR - dorsal fin rays; E - eye diameter; FL - fork length; GR - gill rakers; HD - head depth; HL - head length; IO - interorbital width; LLS - lateral line scales; Max - maxillary length; P_1L - pectoral fin length; P_2L - pelvic fin length; P_1P_2 - pectoral to pelvic length; P_2A - pelvic to anal length; SN - snout length; SL - standard length; SO - snout to occiput length.

Figure 12. Taxonomic measurements made on the Arctic grayling of Great Slave Lake.

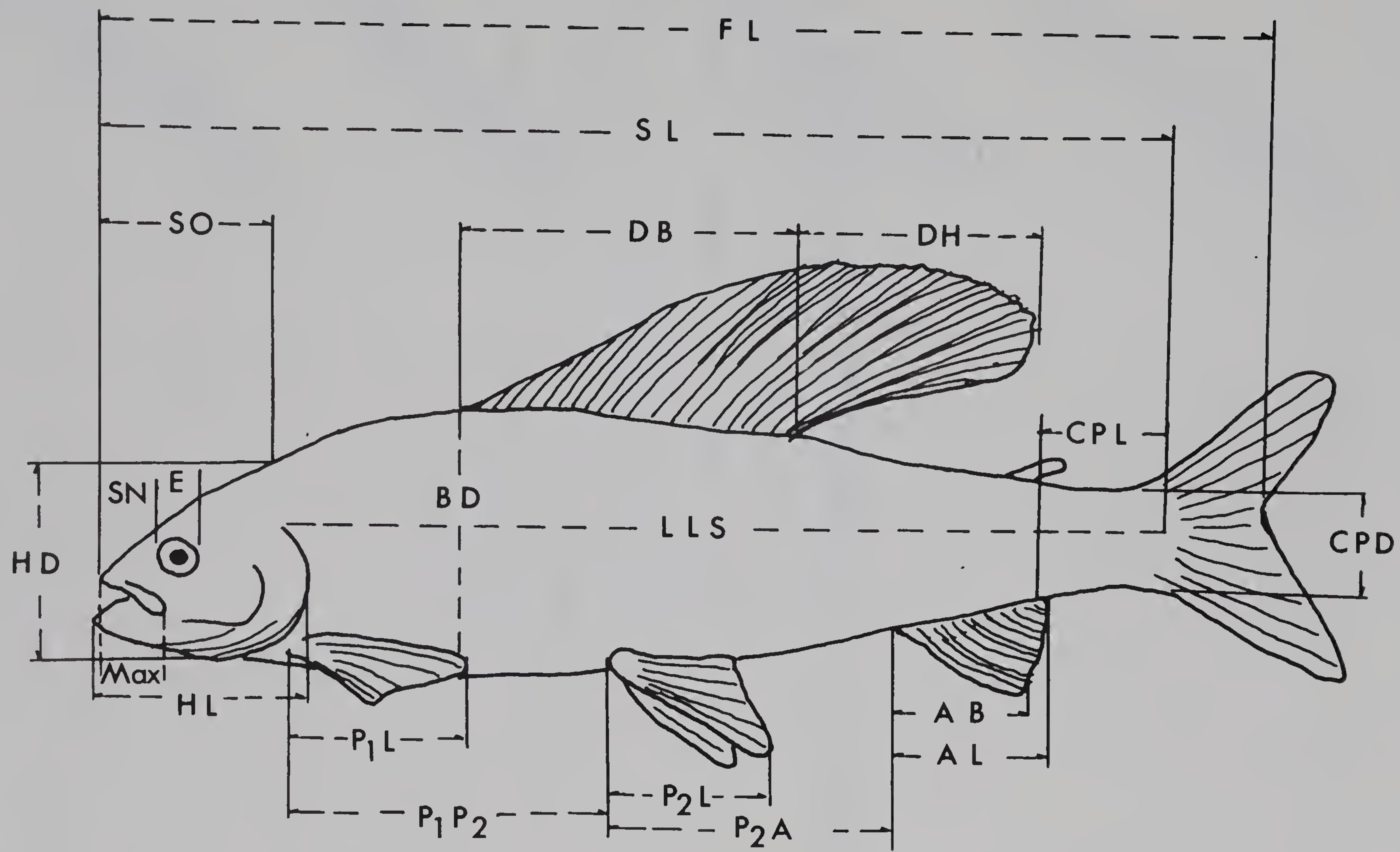
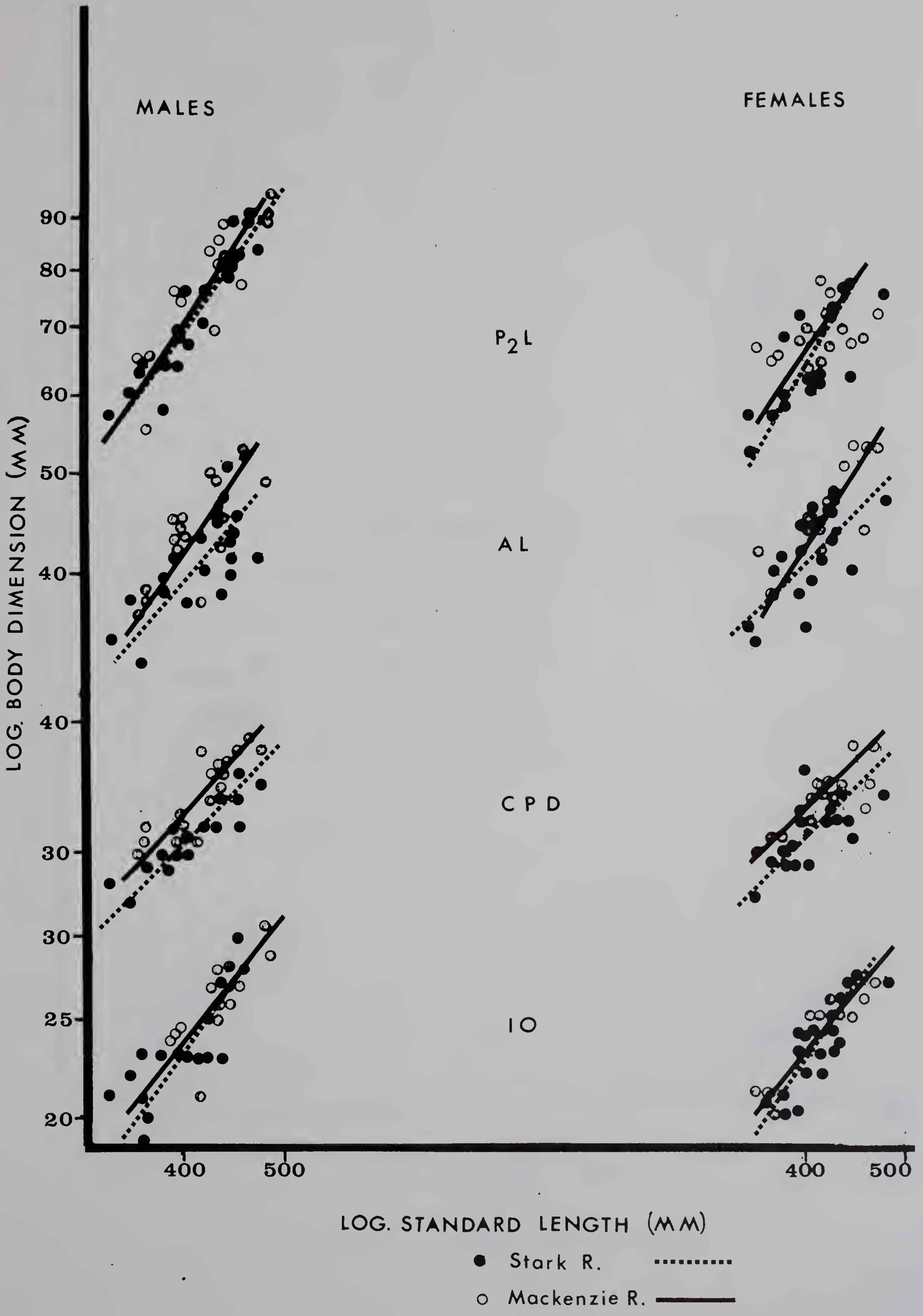

FL
SL
SO
DB
DH
CPL
SN
E
BD
LLS
HD
CPD
Max
HL
P_1L
AB
AL
P_2L
P_1P_2
P_2A

Figure 13. Body dimension measurements. East and West grayling. Logs of the pelvic fin length, anal fin length, caudal peduncle, depth and interorbital width plotted against the log of the standard length. Different origin for each character.



MALES
FEMALES
90
80
70
60
50
40
40
30
30
25
20
P_2L
AL
CPD
IO
LOG. BODY DIMENSION (MM)
400
500
400
500
LOG. STANDARD LENGTH (MM)
Stark R.
Mackenzie R.

Figure 14. Body dimension measurements. East and West grayling. Logs of the dorsal fin height, pectoral fin length, anal fin base and eye diameter plotted against the log of the standard length. Different origin for each character.

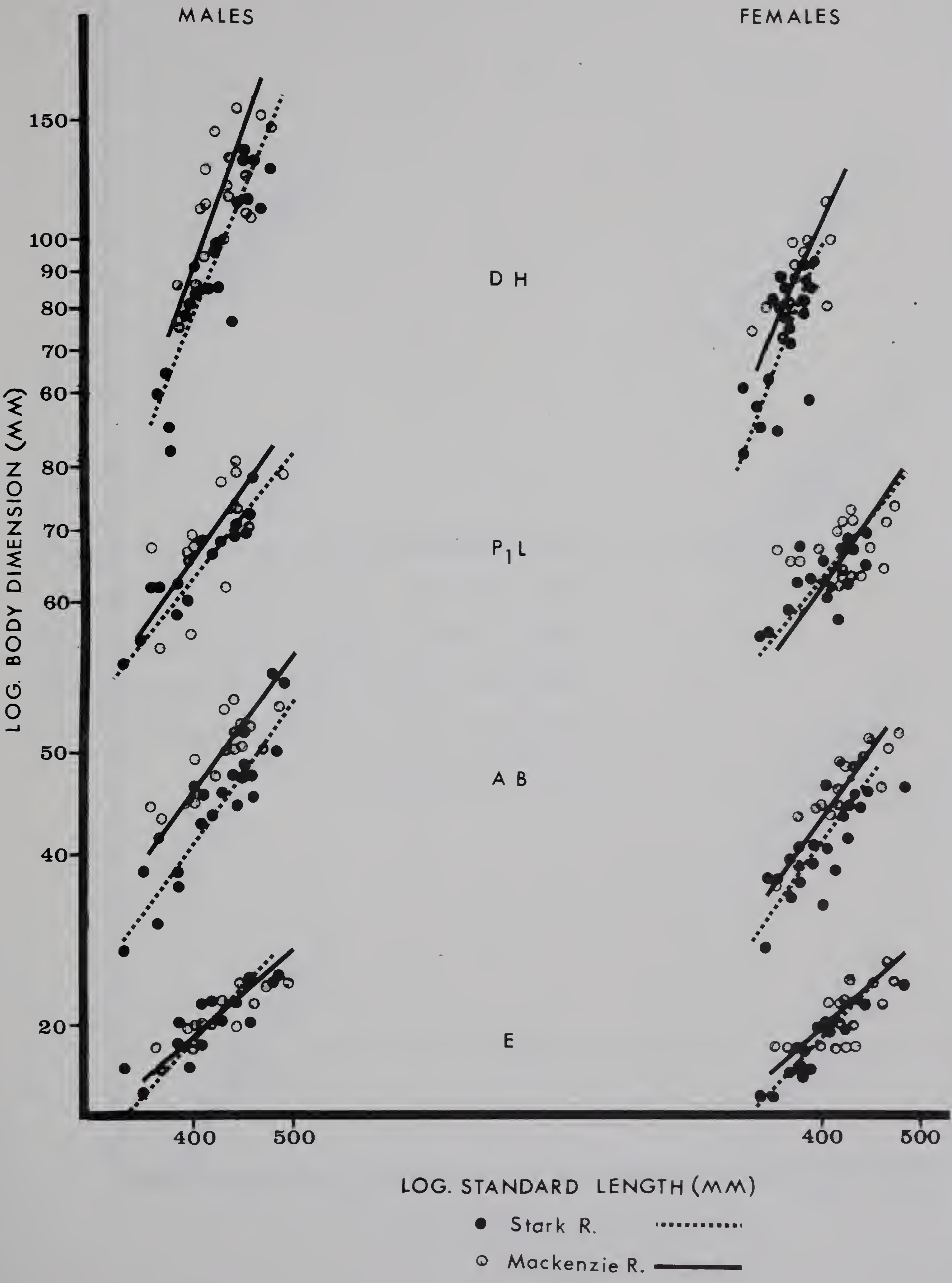

MALES
FEMALES
LOG. BODY DIMENSION (MM)
150
100
90
80
70
60
80
70
60
50
40
20
D H
P_1L
A B
E
400
500
400
500
LOG. STANDARD LENGTH (MM)
Stark R.
Mackenzie R.

Figure 15. Body dimension measurements. East and West grayling. Logs of the head length, caudal peduncle length, maxillary length, and snout length plotted against the log of the standard length. Different origin for each character.

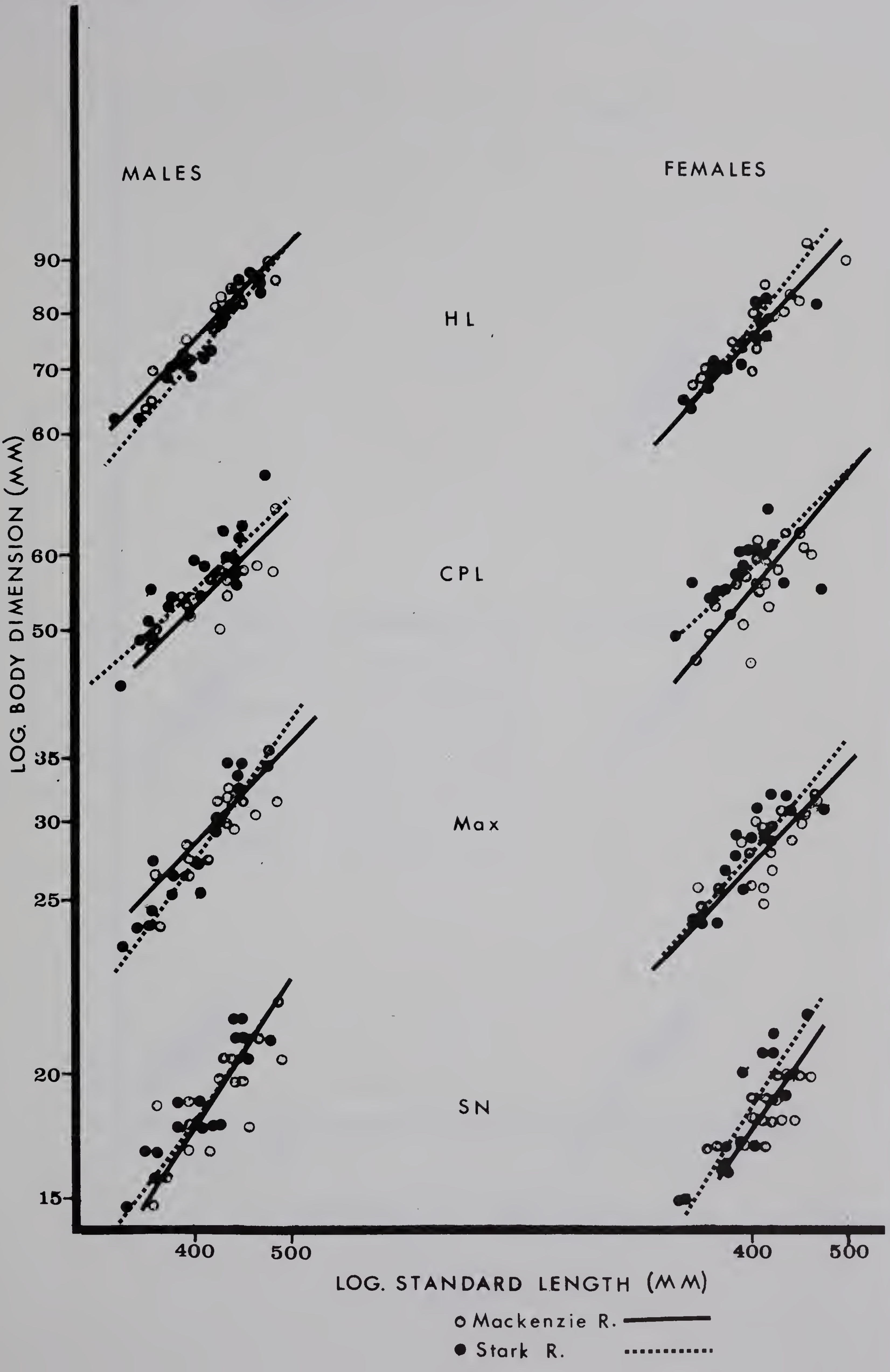
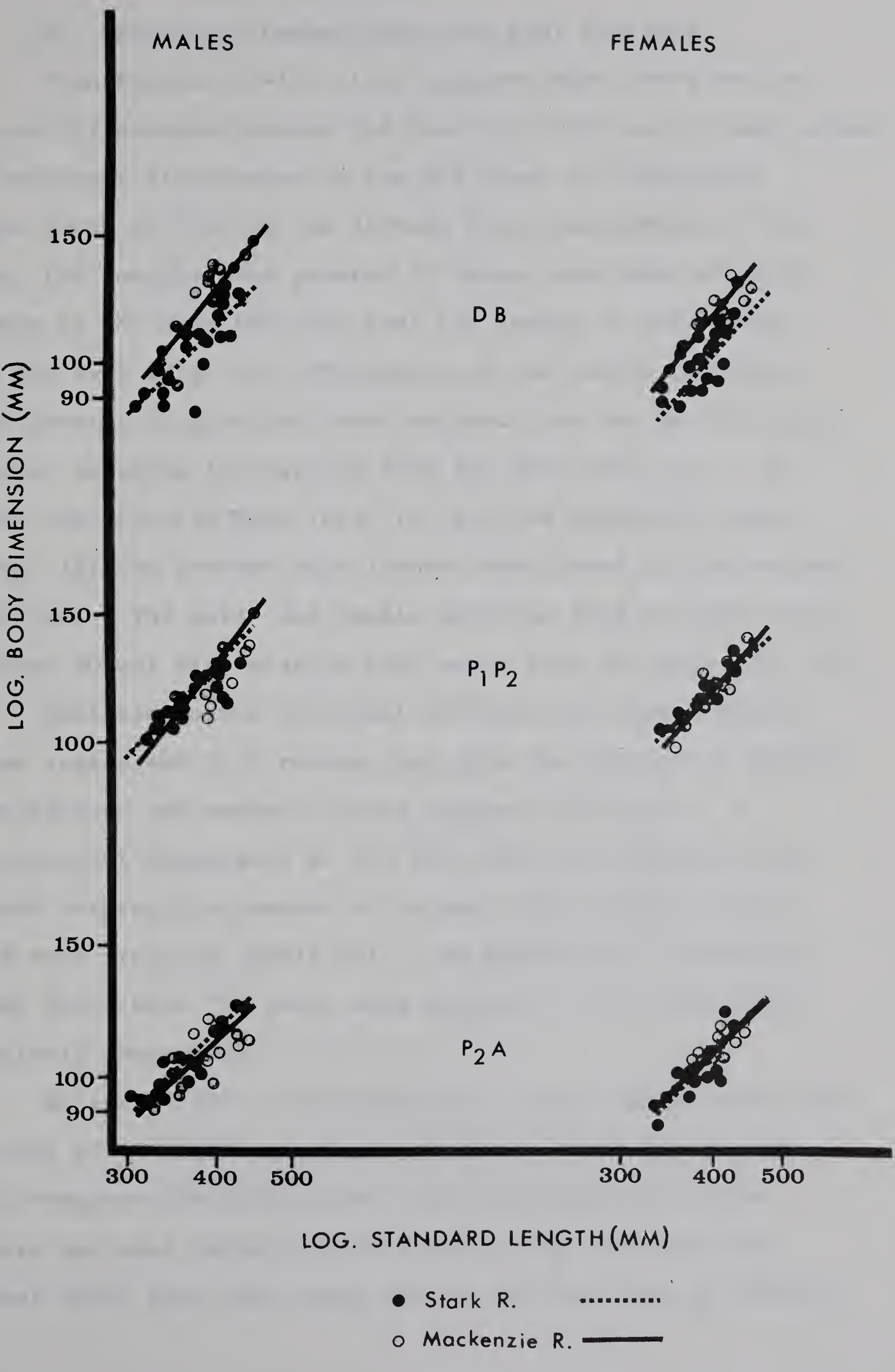

MALES
FEMALES
HL
CPL
Max
SN
LOG. BODY DIMENSION (MM)
90
80
70
60
60
50
35
30
25
20
15
400
500
400
500
LOG. STANDARD LENGTH (MM)
o Mackenzie R.
● Stark R.

Figure 16. Body dimension measurements. East and West grayling. Logs of the dorsal fin base, pectoral to pelvic fin length, and pelvic to anal fin length plotted against the log of the standard length. Different origin for each character.



MALES
FEMALES
LOG. BODY DIMENSION (MM)
150
100
90
150
100
150
100
90
D B
P1 P2
P2 A
300
400
500
300
400
500
LOG. STANDARD LENGTH (MM)
Stark R.
Mackenzie R.

b. Similarity between East and West grayling

From Figures 13-16, it is apparent that there are no major differences between the grayling from the two main areas. Significant differences at the 95% level of confidence were found in five of the fifteen body measurements. The anal fin lengths were greater in larger specimens of both sexes in the West than the anal fin length in both sexes in the East (Fig. 13). The depth of the caudal peduncle was greater in grayling from the West than the depth of the caudal peduncle in grayling from the East (Fig. 13). In both the anal fin base (Fig. 14) and the dorsal fin base (Fig. 16) the greater mean lengths were found in the western grayling. The male and female grayling from the West have higher dorsal fins than do both sexes from the East (Fig. 14).

Meristic counts of dorsal and anal fin rays, lateral line scales and gill rakers also show the similarity between the eastern and western fishes (Tables IV to VII). A significant difference at the 95% level of confidence was found between the numbers of lateral line scales of East and West grayling (Table VII). No significant differences were found when "t" tests were applied to the three other meristic characters.

Walters (1955), in his Table 10, shows the lateral line scales of 69 Arctic grayling. Table IX shows his figures and compares them with those found in Great Slave Lake. There are more lateral line scales in the grayling from Great Slave Lake than there are in the fish used by Walters.

Meristic Counts

Table V. Numbers of dorsal fin rays.

	Average	S.D.
Stark River		
Males	20.45	1.07
Females	20.65	.81
Combined	20.55	
Mackenzie River		
Males	21.85	1.46
Females	22.00	1.03
Combined	21.92	

Table VI. Number of anal fin rays.

	Average	S.D.
Stark River		
Males	12.10	.91
Females	12.20	.95
Combined	12.10	
Mackenzie River		
Males	12.95	.69
Females	12.45	.91
Combined	12.70	

Meristic Counts (cont.)

Table VII. Number of lateral line scales.

Stark River

	Average	S.D.
Males	89.85	3.77
Females	91.45	3.15
Combined	90.65	

Mackenzie River

	Average	S.D.
Males	87.75	3.38
Females	88.25	4.24
Combined	88.00	

Table VIII. Number of gill rakers (left).

Stark River

	Average	S.D.
Males	6.00-12.45	.57-1.15
Females	5.85-12.06	.75- .94
Combined	5.92-12.37	

Mackenzie River

	Average	S.D.
Males	6.25-12.50	.70- .86
Females	6.25- 2.25	.87-1.30
Combined	6.25-12.37	

Table IX. Numbers of lateral line scales of grayling from Great Slave Lake and other sources in North America*

	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	Total	Ave.
Mackenzie River	-	-	-	1	2	1	3	1	1	1	8	4	3	4	4	3	3	-	-	-	-	1	40	88.0
Stark River	-	-	-	-	-	1	-	-	4	-	2	4	4	3	3	6	4	4	3	-	2	-	40	90.7
Walters 1955	1	-	1	6	1	9	10	6	10	6	3	2	3	2	3	3	1	1	-	-	1	-	69	85.1

* Five of Walters' fish were from Great Slave Lake

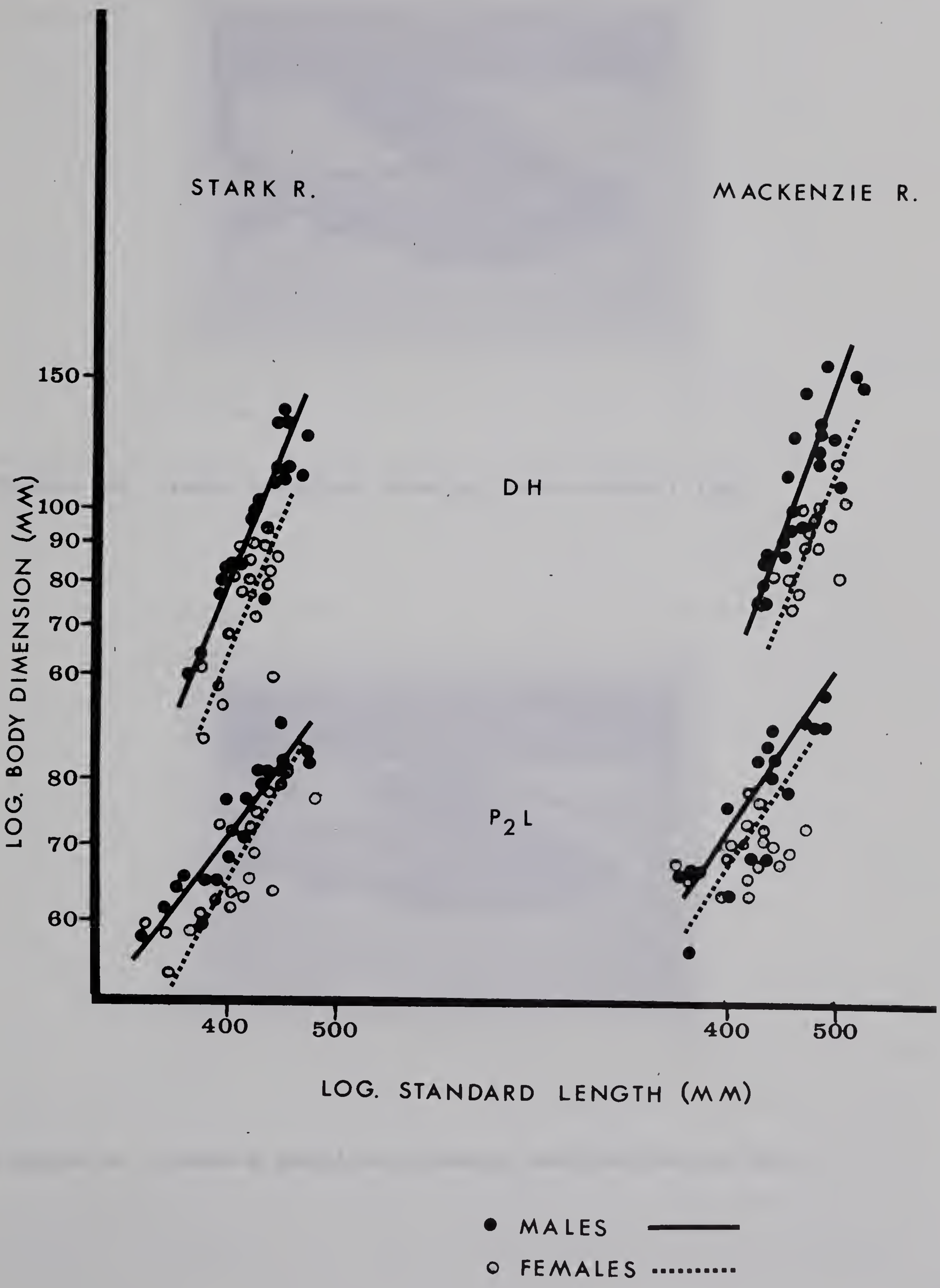
The mean differences between the lateral line scales of the East and West populations is statistically significant. This could mean that inter-population variation for this character is high throughout the range of the species.

The relative position of termination of the maxillary bone is an important taxonomic character because Norden (1959) used it to distinguish among the species of Thymallus. However, this character varies within T. arcticus. Walters (1955) reports that in some Alaskan specimens, the maxillary ends beneath the anterior edge of the pupil of the eye; in adult Great Slave Lake grayling, it ends beneath the middle of the pupil; in Great Bear Lake grayling it ends before the middle of the pupil. My data are at variance with those of Walters for the Great Slave Lake populations; in 20 fish from Stark River and 20 fish from the Mackenzie River, the maxillary ends before the middle of the pupil (Fig. 12).

c. Sexual differences

Significant differences at the 95% level of confidence were found in two of the body measurements. These were in the length of the pelvic fin and in the dorsal fin height (Fig. 17). In both locations, the males had consistently longer dorsal and pelvic fins than did the female grayling. Similar measurements of Arctic grayling from Alberta showed these same secondary sexual differences in the length of the dorsal fin and in the length of the pelvic fins (Ward, 1951).

Figure 17. Body dimension measurements. Male and female grayling. Logs of the dorsal fin height and pelvic fin length plotted against the log of the standard length. Different origin for each character.



STARK R.
MACKENZIE R.
DH
P_2L
LOG. BODY DIMENSION (MM)
150
100
90
80
70
60
80
70
60
400
500
400
500
LOG. STANDARD LENGTH (MM)
MALES
FEMALES

Figure 18. Male grayling showing large dorsal fin.

Figure 19. Female grayling showing smaller dorsal fin.

Rawson (1950) found in Arctic grayling from Saskatchewan that the sex could be identified by the size and shape of the dorsal fin. He reported that the male grayling had a large dorsal fin which is low in front and high behind (Figs. 18 and 19). Other workers found similar results for larger grayling only (Ward, 1951; Wojcik, 1955).

To test the suggested correlation between sex and height of the dorsal fin, I attempted to determine the sex of 307 grayling each more than 40 cm in length, on the basis of height of the dorsal fin. If the dorsal fin reached the adipose fin, or approached it closely, when pressed flat along the back of the fish, then the fish was assumed to be a male. If the dorsal fin was one cm or more short of the adipose fin, then the grayling was called a female. A correlation of 92% was found between sex and height of the dorsal fin.

Wojcik (1955) who also tested this hypothesis, reported no relationship between sex and size of the dorsal fin in 40% of 152 grayling of less than 30 cm fork length. He found a correlation in these characteristics of 66% in adult fish between 30 and 35 cm fork length, and a correlation of 98% in 18 fish over 35 cm in fork length. From these data, it is evident that the sex of grayling less than 35 cm in length cannot be determined with much accuracy from the height of the dorsal fin. The larger the fish is the more positive is the relationship between sex and height of the dorsal fin. In very large grayling over 46 cm fork length, one frequently finds females whose dorsal fin will reach the adipose fin when pressed flat. Males of a similar size usually have the dorsal fin reaching

past the end of the adipose fin.

Further measurements were carried out to see if there was any relationship among the sexes between the area of the dorsal fin and the area of the body. This knowledge would be useful in explaining the behavior of the grayling in certain instances. The outline of each of the 80 grayling used in the morphological study was drawn on paper with the dorsal fin fully extended. Using a polar planimeter, the area of the dorsal fin and the area of the body was determined (Table X). From the results of these measurements it is clear that the dorsal fin area is much greater in males than it is in females, even in fish as small as 34 cm in length. Furthermore, in the Mackenzie River male grayling, the dorsal fin averaged 32.4% of the body area in the larger fish. Males from the East did not show as great a proportional variance (26.2%) but the dorsal fin/body area proportion was certainly much greater than that of females of similar size. These figures substantiate the fact that the dorsal fin heights in the western males and females are significantly larger than those of eastern male and female grayling (Fig. 14).

As the male grayling grows larger its dorsal fin grows proportionately faster. In the female, the dorsal fin does not seem to increase much in size with growth in length (Table X).

The reason for the sexual dimorphism as shown in the dorsal and pelvic fins is undoubtedly related to the behavior of the grayling. These fins are important to the male

Table X. Area of Dorsal fin compared with area of body.
(Total 80 grayling)

Mackenzie River Males

Length Class (mm)	Average Length (mm)	Number of specimens	$\frac{\text{Area Dorsal Fin}}{\text{Area of Body}} \times 100$ (average)
340-389	365.6	3	22.47
390-439	416.8	13	29.49
440-490	468.7	4	32.38

Mackenzie River Females

Length Class (mm)	Average Length (mm)	Number of specimens	$\frac{\text{Area Dorsal Fin}}{\text{Area of Body}} \times 100$ (average)
340-389	369.6	3	20.48
390-439	418.0	13	21.26
440-490	459.2	4	21.48

Stark River Males

Length Class (mm)	Average Length (mm)	Number of specimens	$\frac{\text{Area Dorsal Fin}}{\text{Area of Body}} \times 100$ (average)
340-389	365.1	6	19.52
390-439	415.1	7	22.78
440-490	454.2	7	26.24

Stark River Females

Length Class (mm)	Average Length (mm)	Number of specimens	$\frac{\text{Area Dorsal Fin}}{\text{Area of Body}} \times 100$ (average)
340-389	371.6	6	16.84
390-439	415.6	12	16.15
440-490	460.5	2	15.25

grayling in his displays during spawning and while defending his territory. The importance of these fins is found in the sections on Spawning and Behavior.

It would appear from these results, that the grayling of Great Slave Lake shows definite sexual differences in certain of its body parts. It is also believed that although both main locations have the same species of grayling, there are certain morphological differences between them. Whether these differences are genetic or environmental is not known. They are insufficient to warrant taxonomic recognition.

2. Sex ratio

As mentioned previously, the sex ratio in the spawning run at Providence Creek was 1.3 males to one female, which is not a significant departure from the expected 1:1 ratio. Table XI gives the figures of the total 1965 and 1966 collections and compares the numbers of males and females in both East and West. The 717 males to 383 females caught in the West is a significant departure from the expected 1:1 ratio. The ratio of sexes in the East is about equal with 634 males being caught to 659 females. A suggestion which may explain these sex ratios is offered on page 55.

Wojcik (1955) concluded that grayling in heavily fish-areas develop an unbalanced sex ratio in favor of the females. He proposed that this occurs because

Table XI. Numerical representation of the sexes in each age group for 1965 and 1966 collections.

		Age Group												
Location	Item	1	2	3	4	5	6	7	8	9	10	11	12	Total
East	No. of males	-	42	50	80	137	100	73	52	36	34	20	10	634
	No. of females	-	32	40	64	143	92	74	97	72	27	15	3	659
West	No. of males	3	24	39	32	38	85	106	198	148	33	8	3	717
	No. of females	7	18	31	14	24	73	85	90	35	6	-	-	383

males grow faster than females and therefore would be taken sooner than females. As will be seen (p. 59), the male grayling in Great Slave Lake does not grow much faster than the female grayling so Wojcik's proposal probably does not apply here. Also, it is unlikely that an unbalanced sex ratio would develop in favor of the males just because the area was relatively lightly fished.

3. Age and growth

a. Age

The scales of 2493 grayling were aged in the following manner. The dried scales were observed under a binocular microscope without any preparation of the scales. There was little interference from the epidermis or discoloration on the scales. Agreement on the number of annuli was found on at least three scales before the age was determined for each fish. All fish of six years and older had their scales read a second time at a later date. Some of the more difficult fish were read a third time. The annuli were easily recognizable on fish five years and younger; the older the fish after six years, the more difficult it became to discern the annuli. A sample of scales was sent to F. M. Atton to check my readings, and in most cases the results were the same. Although I had no known-age fish to compare my results with I believe my readings are accurate for fish up to ten years of age.

On June 19, 1966, 51 fry were collected from Providence Creek by D. G. Buchwald who used an electric shocker for

collection purposes. Presuming the fry were hatched in the spring of that year, they would be approximately three weeks old. The average fork length of the fry was 25 mm and none had scales yet. On July 10 and 12, two small grayling were caught in the same creek. These fish were then about seven weeks old. The average fork length was 51.6 mm. The fish had scales along the lateral line, although there were no scales just anterior and antero-lateral to the dorsal fin, or on the ventral side of the fish. The scales from the lateral line area had three circuli (Table XII).

Fry caught at Stark River in August, 1964 by J. J. Keleher and in August, 1965, also showed similar appearance to the last described case. The average fork length of the eight fish from Stark River was 49.5 mm. There were five circuli on each scale in the lateral line area. Brown (1943) observed that scale formation on Montana grayling took place at a total length of 35.5 mm. Similar results were found by Gustafson (1948) for Thymallus thymallus L. and Schallock [n.d.] for Arctic grayling in Alaska. Miller (1946) reported that none of the fry collected from Great Bear Lake under 44 mm had scales. He assumed that the first scales arrived when the fish were about 50 mm.

Fish were aged as follows: if no annuli were found they were called age 0; if one annulus, age 1: two annuli, age 2; etc.

Table XII. Number of circuli and fork length of some age group O grayling.

Fork length mm	Number of circuli	Location	Date of capture
19.1	no scales	Prov. Cr.	June 19, 1966
21.3	"	"	"
22.4	"	"	"
26.5	"	"	"
29.6	"	"	"
42.5	3 circuli	"	July 10, 1966
45.2	5 circuli	Stark R.	August, 1966
52.4	"	"	"
57.8	7 circuli	"	"
63.1	9 circuli	"	"

b. Formation of the annulus

A count was made of 172 fish from the East of Great Slave Lake and 162 fish from the West, to see when the fish started to lay down new circuli outside of the last annulus or year-mark. Table XIII shows that by July 8 in the East, 86% of the fish had one to two circuli outside the last annulus. In the West it appeared that the grayling start growing at a slightly later period, for not until July 19 were there 80% of the fish with circuli outside of the last annulus. This apparent lag of the western fish behind the eastern fish in the beginning of growth may have been due to the fact that the western fish were taken in 1965 and the eastern fish were taken in 1966. In any event, by the end of July, most of the fish from both locations had started to grow.

Kruse (1959) found that all of his grayling from Wyoming had circuli beyond the last annulus after June 26. Schallock [n.d.] found that 58% of a sample of 100 grayling from Alaska had circuli outside the annulus by July 8. From this it appears that the Arctic grayling from Great Slave Lake lay down the first circulus after the annulus, at about the same time as the Arctic grayling from Alaska.

No real time can be assigned to the period when the annulus itself is formed but it would appear that it is during the period immediately preceding the laying-down of the new circuli (i.e. before June). This period would correspond with the time that spawning marks would be laid down so there should be no interference from such marks.

Table XIII. Time of laying down of the first circuli.

	Location	Time period	No. examined	% Fish with circuli outside last annulus
East	Stark River	June 4-June 10	28	25 %
	Stark River	June 11-June 21	33	33.3%
	Stark River	June 22-June 30	63	42.8%
	Stark River	July 1-July 8	48	85.8%
West	Kakisa River	June 1-June 5	20	0 %
	Mackenzie R.	June 25-June 30	32	56 %
	Mackenzie R.	July 1-July 8	69	52 %
	Mackenzie R.	July 9-July 19	41	80.4%

Schallock [n.d.], working with the scales of Arctic grayling in Alaska, found that an annulus was not formed during the growth period of the O-plus year and that an annulus was laid down in the 1-plus growth period but was later reabsorbed. As a result, scale reading techniques tended to under-age the grayling. Schallock added a year to his scale reading results to correct this missing year mark. Kruse (1959) also reported difficulty in finding the first annulus.

It is my belief that the grayling of Great Slave Lake do not reabsorb their first year annulus, as a count of the circuli in the one and two year old fish, showed that the number of circuli up to the first annulus remains fairly constant at about 13 to 14 in both groups (Table XIV). As some of the fish in the August, 1965, O age group already had as many as nine circuli (Table XII), it is not unreasonable to assume that they could reach 13 or 14 circuli by the end of their first growing season. Second-year fish laid down another 13 circuli, on the average, to the second annulus.

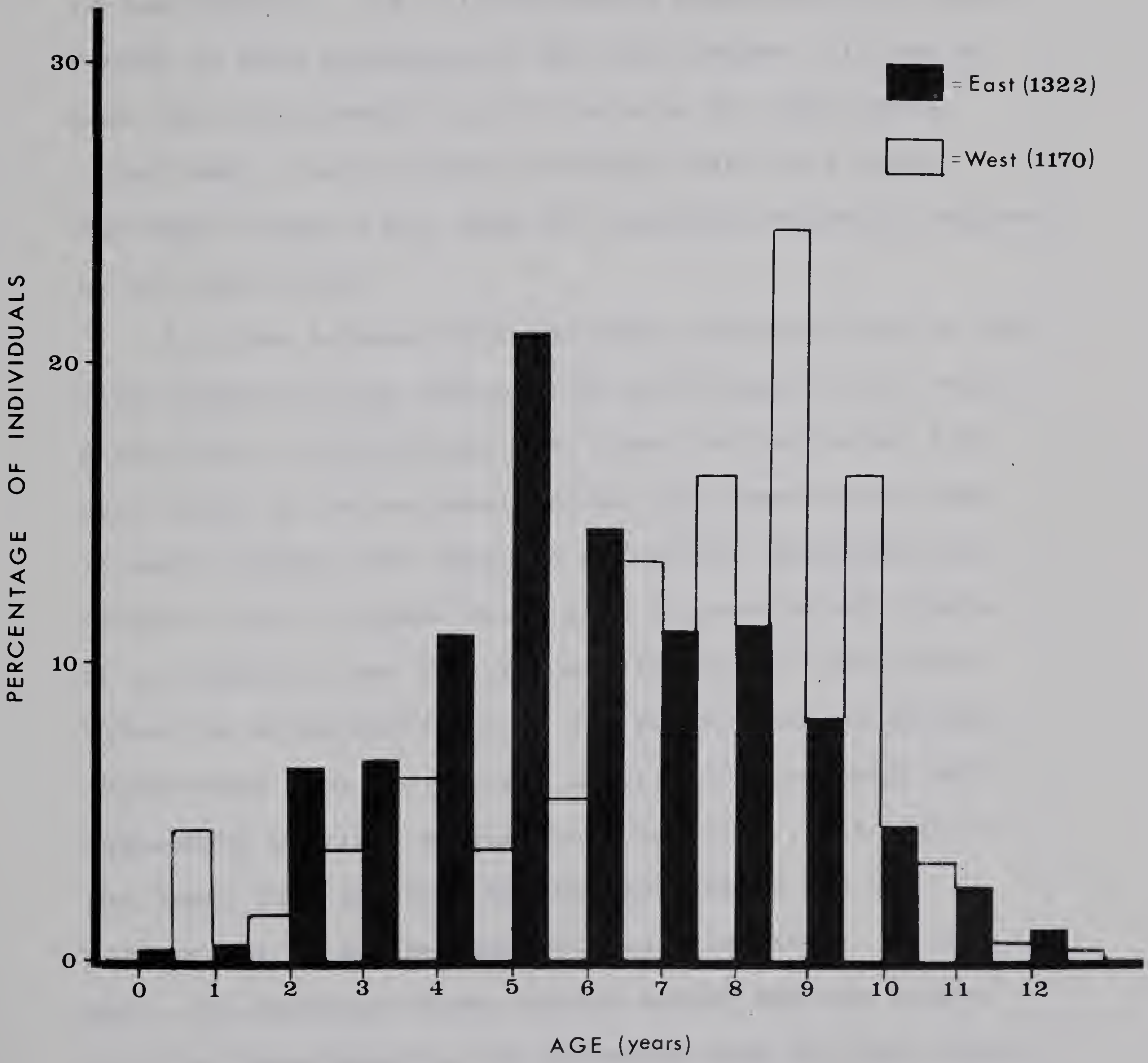
c. Age composition

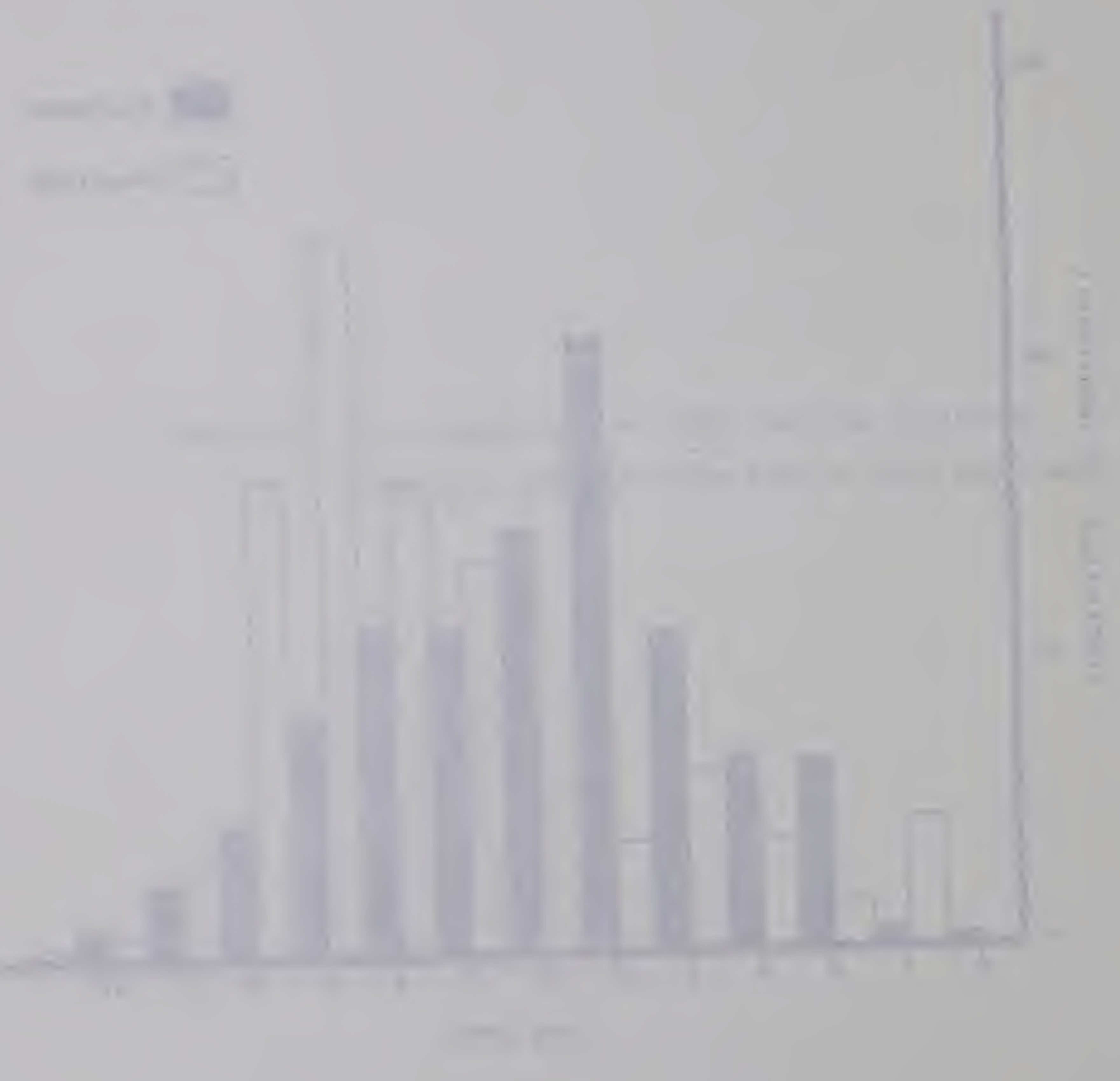
The age composition of the grayling caught in each main location varied considerably (Fig. 20). In the East, there were many more five-year old grayling caught than any other age. In the West there were many more eight-year old fish caught than any other age. Some difference could have been caused by a gear selection bias, as it has been

Table XIV. Counts of circuli to first annulus.

Age	No. fish examined	Average no. of circuli	Range
one	10	14	8-17
two	10	13	7-20

Figure 20. Age composition of 2492 grayling collected from East and West locations in 1965 and 1966.

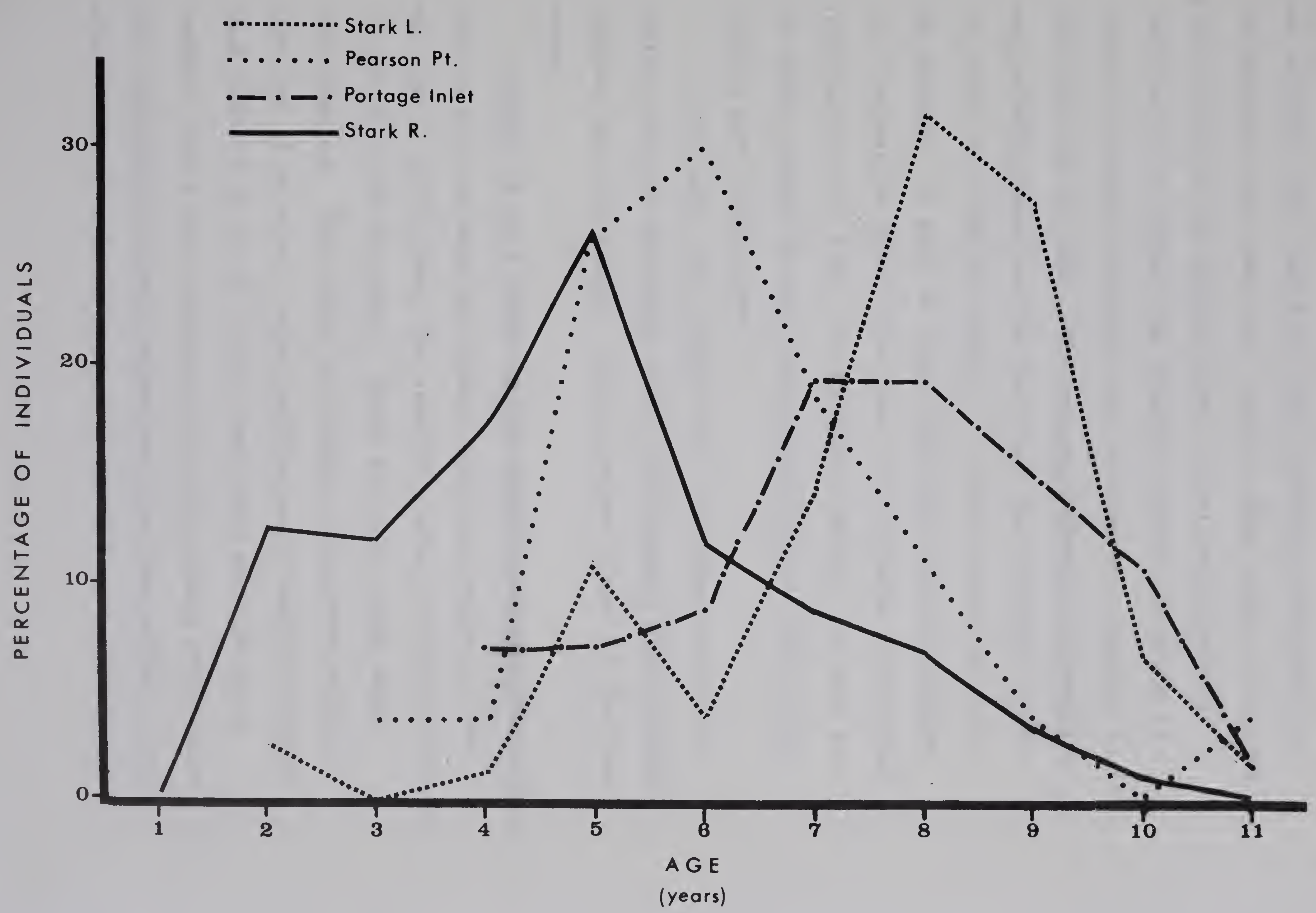

= East (1322)
= West (1170)
PERCENTAGE OF INDIVIDUALS
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
11
12
AGE (years)



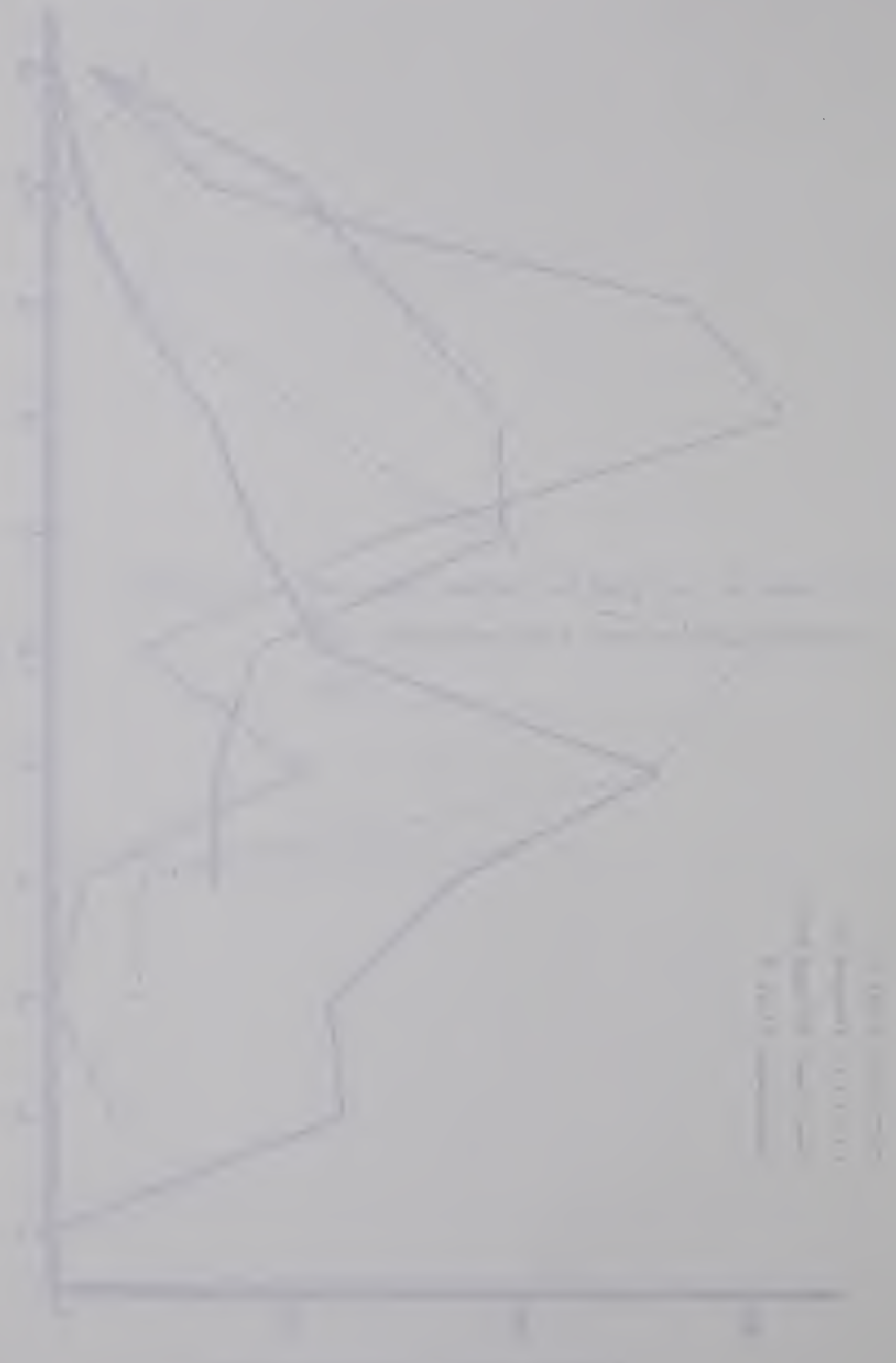
shown that angling tends to catch smaller fish than gill nets (see p. 26). Because 62% of the grayling from the East were taken by angling in the Stark River, it is likely that these fish have biased the whole eastern sample to some degree. Fig. 21 represents graphically the fish caught in 1965 according to age and numbers. It can be seen that fish caught by gill nets in the lake areas (Stark Lake, Pearson Point, Portage Inlet) are older, and hence larger fish, than the grayling caught by angling in the Stark River.

I do not believe that the gear selection bias is the whole answer to why younger fish were found in the Stark River than in surrounding lake areas and why older fish were found in the Mackenzie River with fewer young ones. It would appear that there is a definite preference for certain areas in Great Slave Lake by certain age groups. It is proposed that the younger, sub-adult fish (those below the approximate age of six years) tend to occupy a region away from the larger, mature and presumably more aggressive grayling of six years and older. If this is the case, then it could be the explanation for the differences in age between the two main areas. In the West, the Mackenzie River region around Brabant Island, could be considered as the preferred area for the larger, older grayling, as there are many islands and shore areas for the grayling to choose territories from. It is not known where the majority of the younger fish are located in the West, but as the Mackenzie River is so large, it is

Figure 21. Per cent number of grayling of ages 1 to 11, occupying four Eastern locations in 1965.



Stark L.
Pearson Pt.
Portage Inlet
Stark R.
PERCENTAGE OF INDIVIDUALS
0
10
20
30
1
2
3
4
5
6
7
8
9
10
11
AGE
(years)

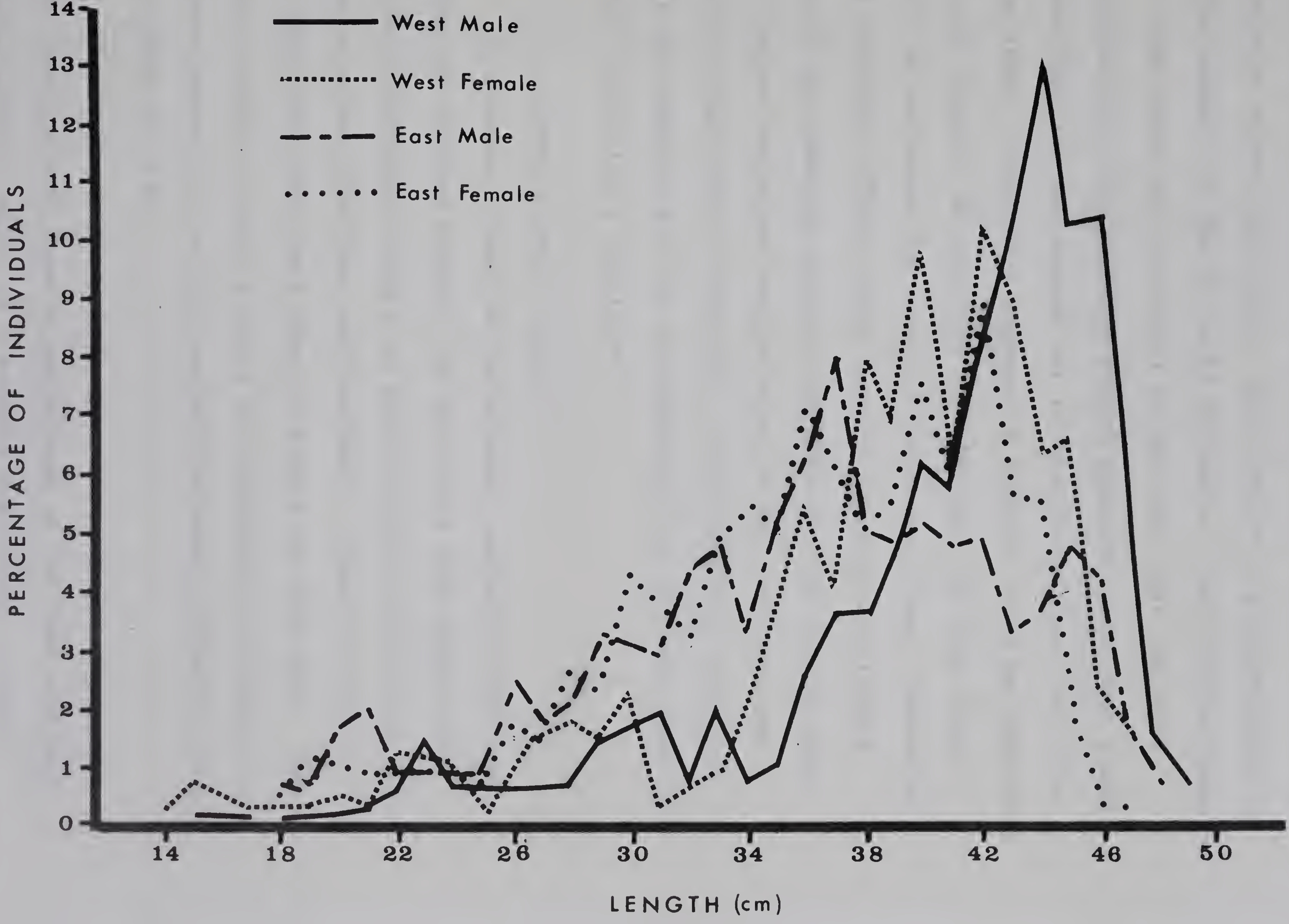


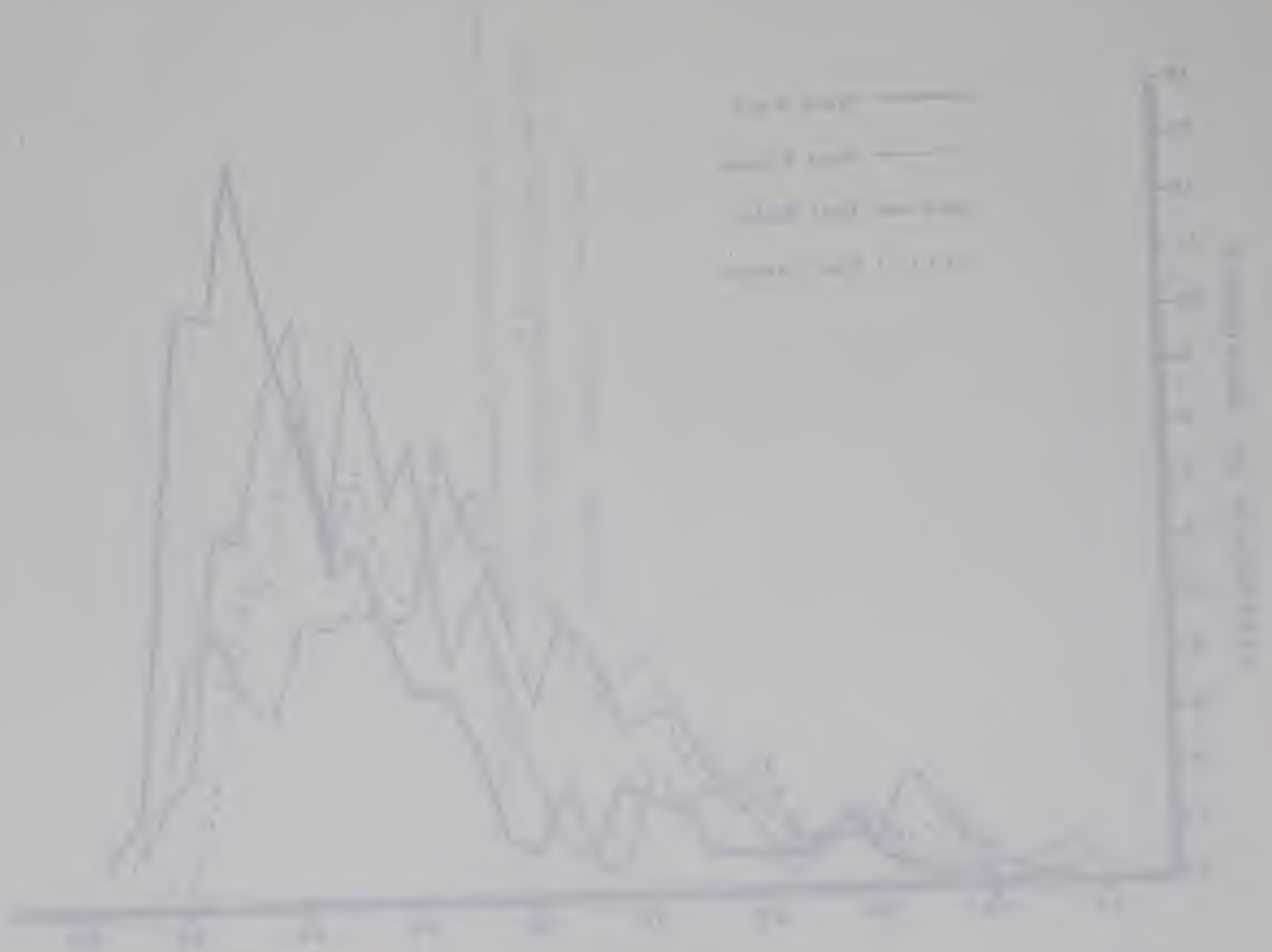
not unlikely that there are many locations available to the grayling that were not found in this study. One such place could be the Kakisa River, which definitely has grayling in it during the spawning season but which is reputed by sports fishermen not to have any grayling in it after the end of June. The reported absence of grayling was probably based on the fact that the fishermen could not catch any fish by angling. In the section on Food and Feeding, it will be shown that the grayling changes its food habits about this time. It is quite likely that grayling are, in fact, in the Kakisa River, but they are not being caught by the spin-casting methods used in the earlier part of the year.

In the East, the younger fish are found mainly in regions such as the Stark River, and perhaps other unknown regions, and the larger, older fish are found in the lake areas.

Figure 22 is a graph of the length-frequency distribution of all the male and female grayling caught in 1965 and 1966. In the West the greatest number of fish are found in the 40 to 46 cm range. There are more large males than females. The number of females diminishes rapidly past the 45 cm size. Male grayling were caught in fairly good numbers up to 47 cm and some males were 50 cm in length. There were relatively few fish taken below 36 cm. This distribution again emphasizes that the Brabant Island area of the West is preferred by the older, larger fish.

Figure 22. Length-frequency distribution of both sexes of 2408 grayling caught in East and West locations. (Numbers in per cent)


West Male
West Female
East Male
East Female
PERCENTAGE OF INDIVIDUALS
LENGTH (cm)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
14
18
22
26
30
34
38
42
46
50



In the East, it is seen that the greatest number of males are found in the 37 cm range (this is the approximate size of a 5-year old fish). The females are represented in large numbers in the 37 to 43 cm range. The relative absence of large males may be caused by the fact that the male grayling are just reaching sexual maturity about age 5 and hence they are now moving out of the Stark River into the lake areas. The large numbers of females could be explained if most females do not hold territories, for then there would be no reason for them to leave the river. Fabricius and Gustafson (1955) found females holding territories during the spawning season, but they did not occupy them as long as the males and the size of the territory was smaller than that of the males. This probably indicates that the females are not as aggressive as the male when it comes to holding a territory.

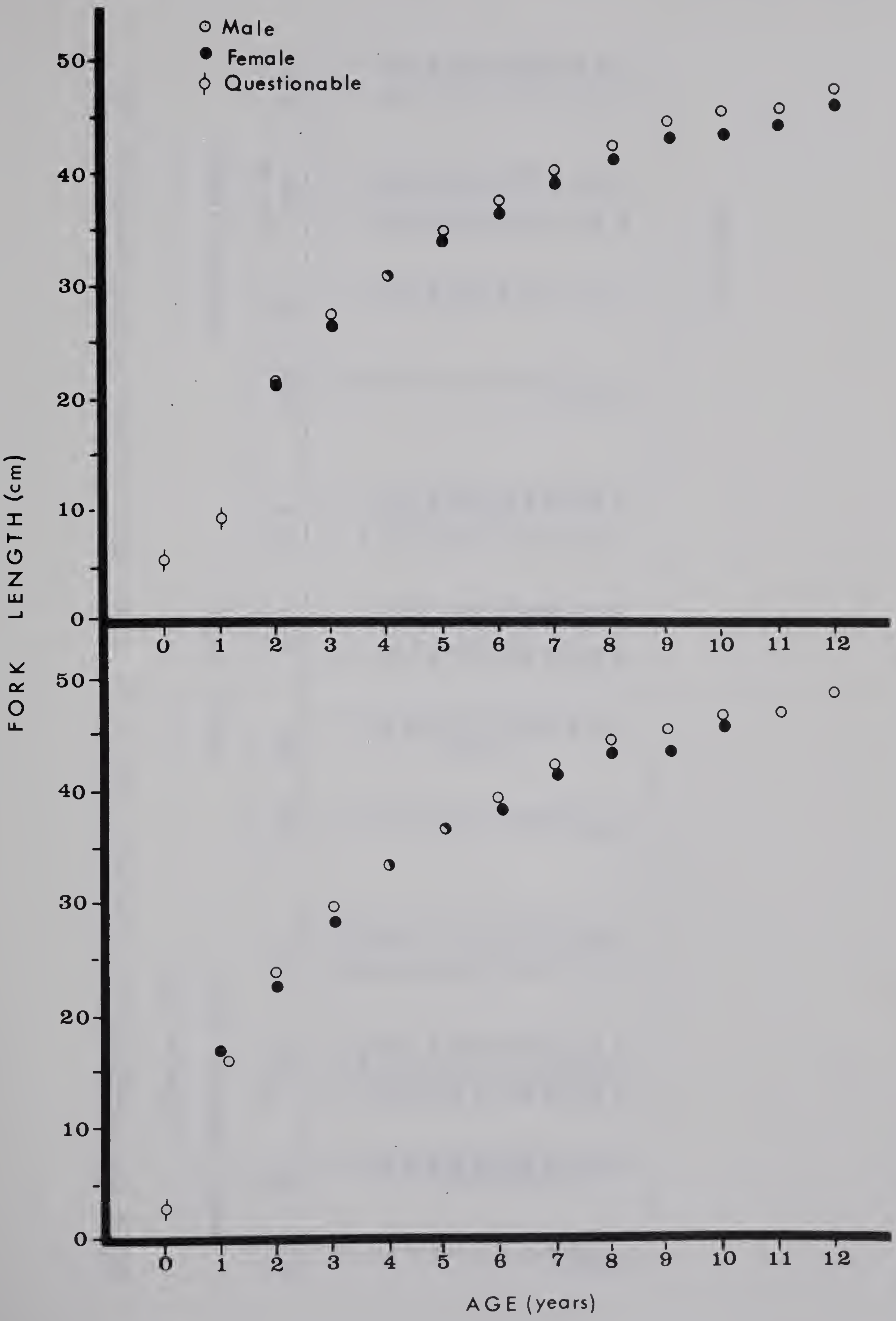
d. Growth curves (length)

In Figures 23 and 24 the average length of each age group was plotted against the age (data from Table XV). The male grayling appears to grow slightly faster than the female in both the East and the West. Growth is rapid to about the sixth year when it starts to slow down. The lined circles in both figures are combined sex figures as it was impossible to distinguish the sexes during the first two years of life.

Figure 25 combines both males and females from each main location and shows a comparison of the East and West growth curves. There is a notable difference in size

Figure 23. Growth curves of grayling from the East. (length vs age)

Figure 24. Growth curves of grayling from the West. (length vs age)


Male
Female
Questionable
FORK LENGTH (cm)
AGE (years)
0
10
20
30
40
50
0 1 2 3 4 5 6 7 8 9 10 11 12

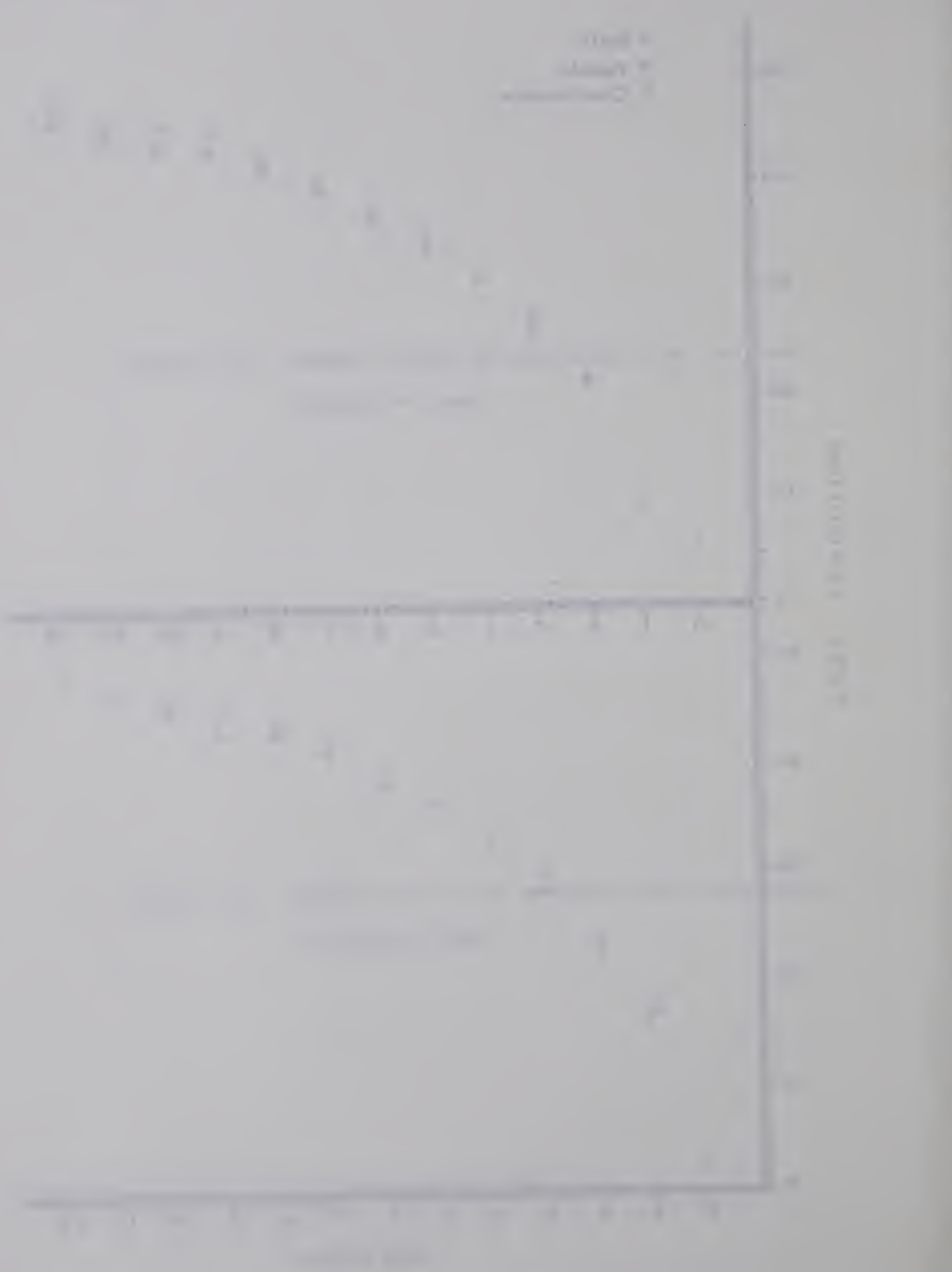


Table XV. Averages and standard deviations of the fork lengths of 2493 grayling, age groups 0-12.

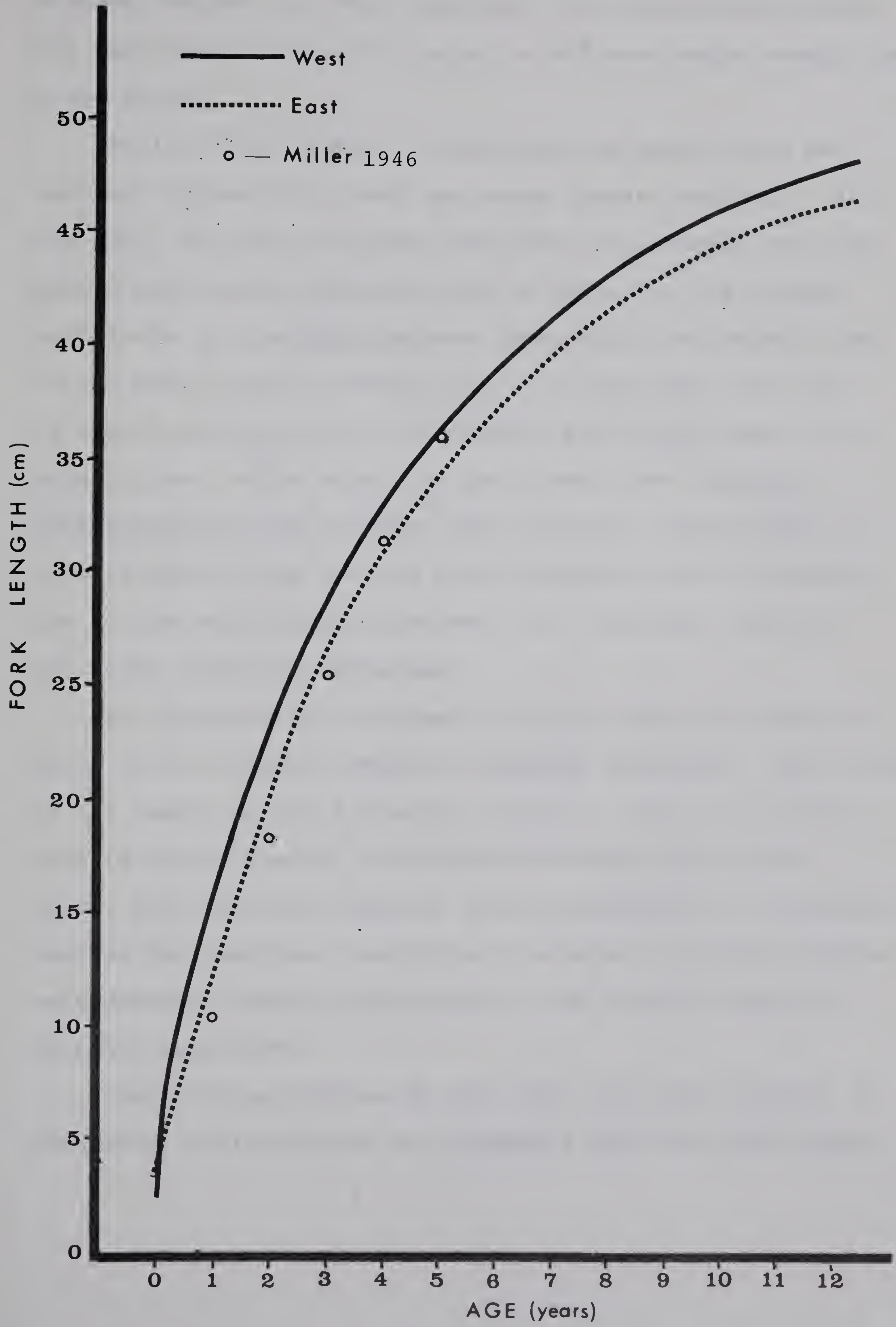
Sexes combined (East)				Males (East)				Females (East)			
Age	No.	Av. L. (cm)	S.D.	Age	No.	Av. L. (cm)	S.D.	Age	No.	Av. L. (cm)	S.D.
0	5	5.6	5.52	0	-	-	-	0	-	-	-
1	8	9.47	6.93	1	-	-	-	1	-	-	-
2	84	20.54	2.53	2	42	21.02	1.90	2	32	21.09	2.27
3	92	26.67	2.36	3	50	27.01	2.51	3	40	26.27	2.16
4	146	30.39	2.07	4	80	30.52	2.08	4	64	30.29	1.96
5	280	34.49	2.41	5	137	34.90	2.28	5	143	34.09	2.49
6	194	37.26	1.93	6	100	37.79	1.88	6	92	36.67	1.83
7	147	39.73	1.87	7	73	40.09	1.83	7	74	39.38	1.85
8	149	41.73	1.59	8	52	42.48	1.24	8	97	41.33	1.62
9	108	43.66	1.63	9	36	44.68	1.31	9	72	43.16	1.55
10	61	44.47	1.80	10	34	45.52	1.41	10	27	43.15	1.32
11	35	44.99	1.49	11	20	45.72	1.45	11	15	44.03	0.94
12	13	47.05	0.71	12	10	47.09	0.76	12	3	46.90	0.63

continued

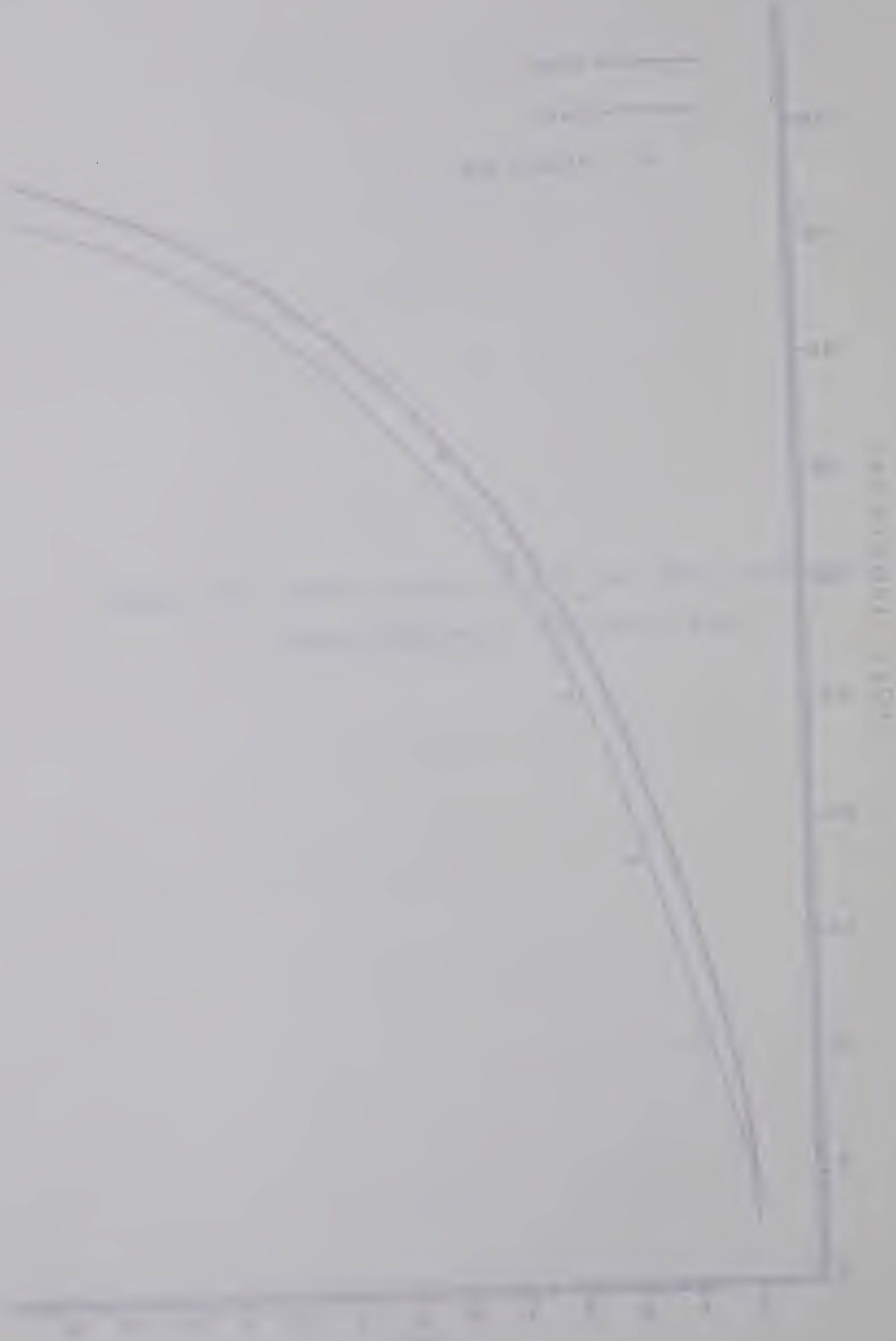
Table XV. Continued

Sexes combined (West)				Males (West)				Females (West)			
Age	No.	Av. L. (cm)	S.D.	Age	No.	Av. L. (cm)	S.D.	Age	No.	Av. L. (cm)	S.D.
0	51	2.51	2.68	0	-	-	-	0	-	-	-
1	18	15.91	1.35	1	3	16.07	1.10	1	7	16.47	1.39
2	46	23.28	1.52	2	24	23.61	1.39	2	18	22.86	1.57
3	71	29.03	1.78	3	39	29.45	1.81	3	31	28.49	1.63
4	46	33.29	2.28	4	32	33.15	2.19	4	14	33.61	2.54
5	62	36.77	1.90	5	38	36.65	2.23	5	24	36.96	1.23
6	158	38.75	2.24	6	85	39.26	2.04	6	73	38.17	2.33
7	192	41.63	2.06	7	106	41.96	2.12	7	85	41.24	1.93
8	291	43.78	2.04	8	198	44.09	1.97	8	90	43.05	2.04
9	183	44.75	2.11	9	148	45.04	1.84	9	35	43.54	2.69
10	40	45.68	5.69	10	33	46.56	1.62	10	6	46.43	1.18
11	8	46.98	1.32	11	8	46.98	1.32	11	-	-	-
12	4	48.58	1.01	12	3	48.80	1.10	12	-	-	-

Figure 25. Growth curves of East and West locations, sexes combined. (length vs age)



West
East
o — Miller 1946
FORK LENGTH (cm)
0
5
10
15
20
25
30
35
40
45
50
0 1 2 3 4 5 6 7 8 9 10 11 12
AGE (years)



between the East and West grayling, with the grayling from the West being constantly larger in all age groups except the 0-age group.

Table XVI and Figure 26 describe the growth as a percentage increment for each age group (sexes combined). In the East, the rate of growth declines continuously from the second year to the eleventh year of life. In the twelfth year there is a slight increase shown which is probably due to the small sample involved (13). In the West, the rate of growth declines until the seventh year where there is a slight rise. After this rise the growth rate declines continuously to the eleventh year of life. Again there is a small rise in the twelfth year and again this is probably due to the small sample involved (4). The small rise at age seven cannot be explained.

The large growth increment (117.1%) shown for the Age 2 group of th- eastern sample is probably incorrect. This could be the result of the following factors. First, the sample size is small; second, the variance is high (S.D. 619); third, the fish were measured after preservation in formalin, whereas the specimens comprising the other age group samples were measured before preservation. The correct figure is probably about 50%.

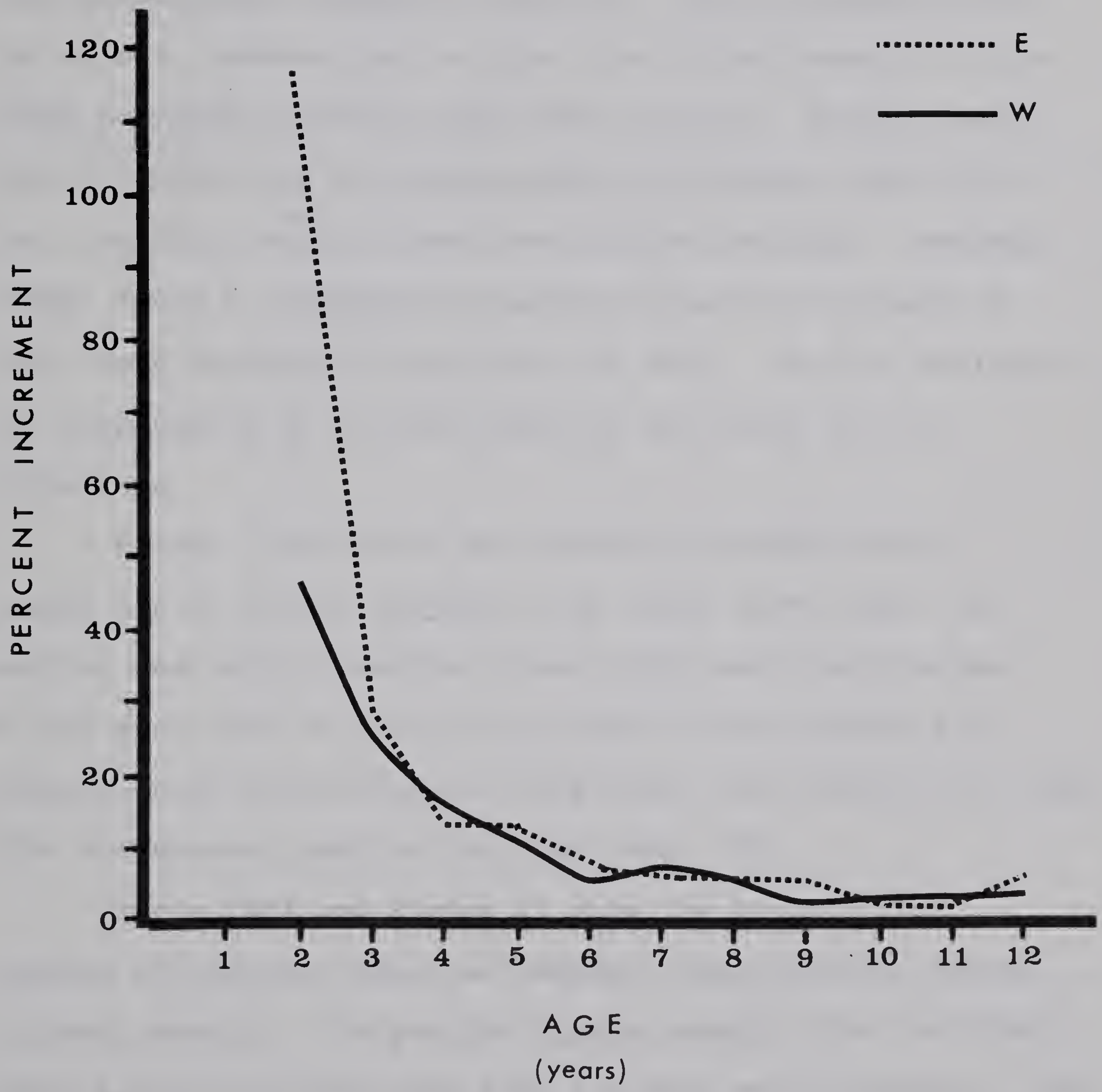
Table XVI and Figure 26 also show that the grayling in both main locations grow at increments that are quite close

Table XVI. Growth rate expressed as percentage increment of each age group.

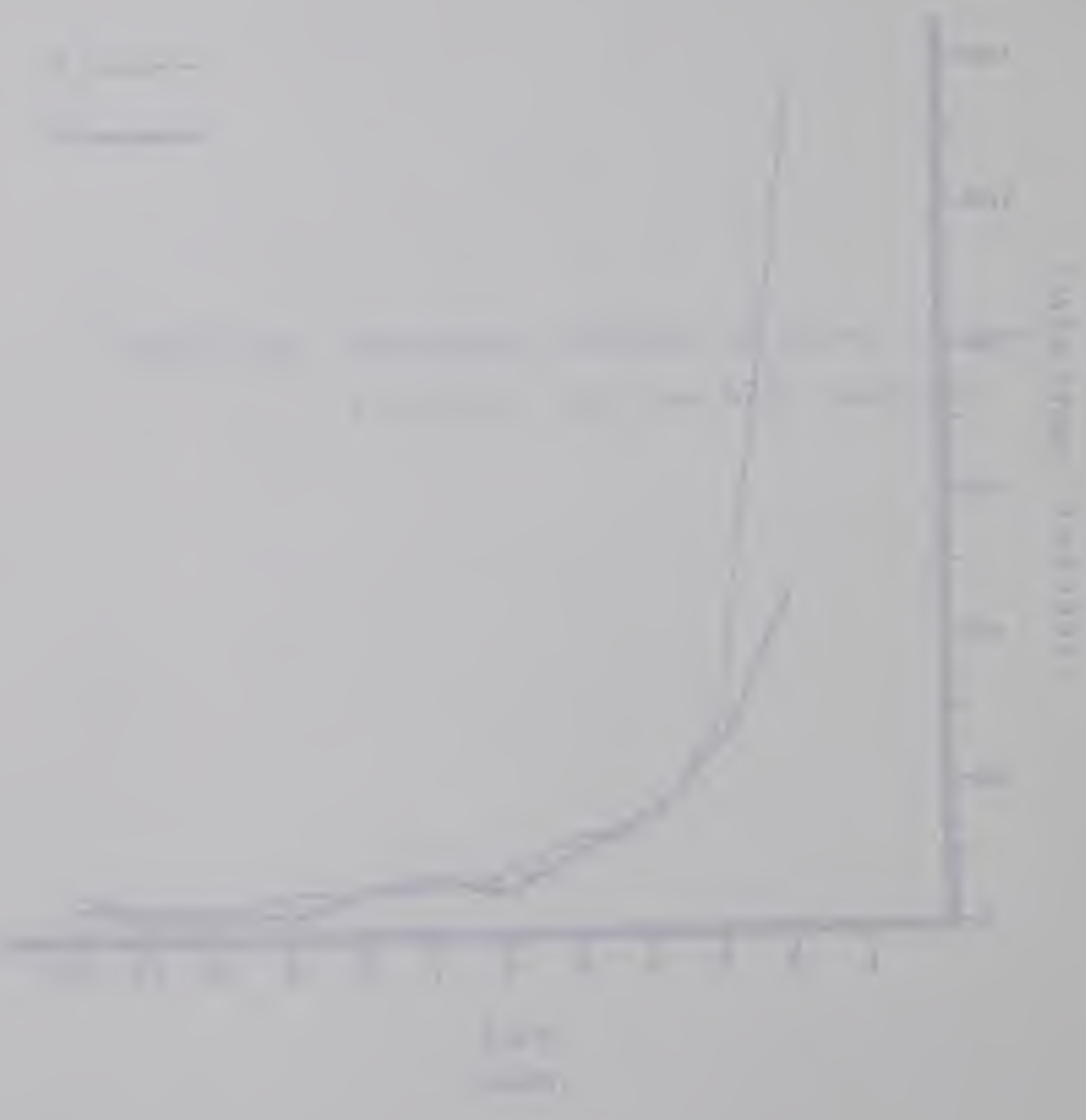
$$\frac{100\ \Delta L}{\text{Sum}\ \Delta L} = \%\ \text{increment}$$

	East			West		
Age group	ΔL mm	Sums ΔL	% increment	ΔL mm	Sum ΔL	% increment
1	94.6	94.6	-	159.1	159.1	-
2	110.8	205.4	117.1	73.6	232.7	46.3
3	61.3	266.7	29.8	57.5	290.2	24.7
4	37.2	303.9	13.9	42.6	3332.8	14.7
5	40.9	344.8	13.4	34.8	367.6	10.5
6	27.7	372.5	8.0	19.8	387.4	5.4
7	24.7	397.2	6.2	28.8	416.2	7.4
8	20.0	417.2	5.0	21.5	437.7	5.2
9	19.3	436.5	4.6	9.7	447.4	2.2
10	8.1	444.6	1.9	9.2	456.6	2.1
11	5.2	449.8	1.2	13.0	469.6	2.8
12	20.5	470.3	4.6	16.0	485.6	3.4

Figure 26. Percentage increment of growth in years 2 to 12 for East and West locations.



E
W
120
100
80
60
40
20
0
PERCENT INCREMENT
1
2
3
4
5
6
7
8
9
10
11
12
AGE
(years)



to one another, thereby substantiating the curves of Fig. 25. It is not known where the fish from the West and the Fish from the East begin to diverge in size but it must be presumed that it is in the 0 to 1 age group. Because collections of grayling in the 0 to 1 age group are small, and because they were not taken at similar time periods, this presumption cannot be verified. It is possible that the colder, eastern part of the lake is detrimental to the young grayling in their first year of life. For instance the cold water may be unfavourable for certain food items that grayling require immediately after hatching. Kennedy (1954) found a difference between the rates of growth of lake trout between the East and the West. He also believed the temperature of the two areas as the cause of the difference.

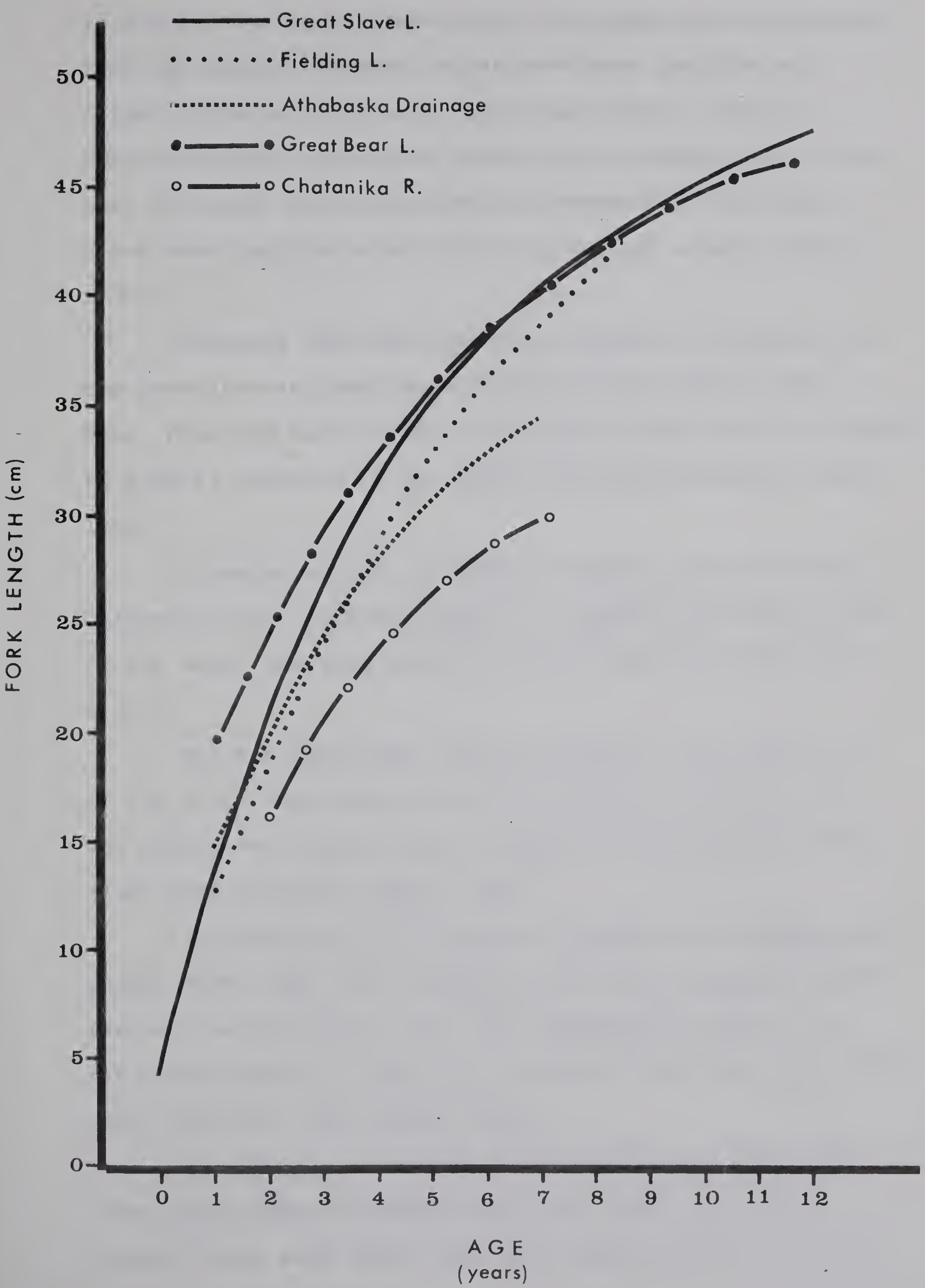
Miller (1946) gave the average calculated fork length for 23 Arctic grayling from Great Slave Lake. No mention was made of whether these fish came from the East or the West part of the lake but when these figures are plotted on my growth curves, they agree with figures for fish from the Eastern part of the lake (Fig. 25).

Table XVII and Figure 27 show the average fork lengths of grayling taken at capture, from various sources in North America. To get the single growth curve for Great Slave Lake, the values for East and West were averaged. The growth curve of the Great Bear Lake grayling most closely approximates the Great Slave Lake curve. The grayling in each age group in Great Bear Lake are larger than grayling

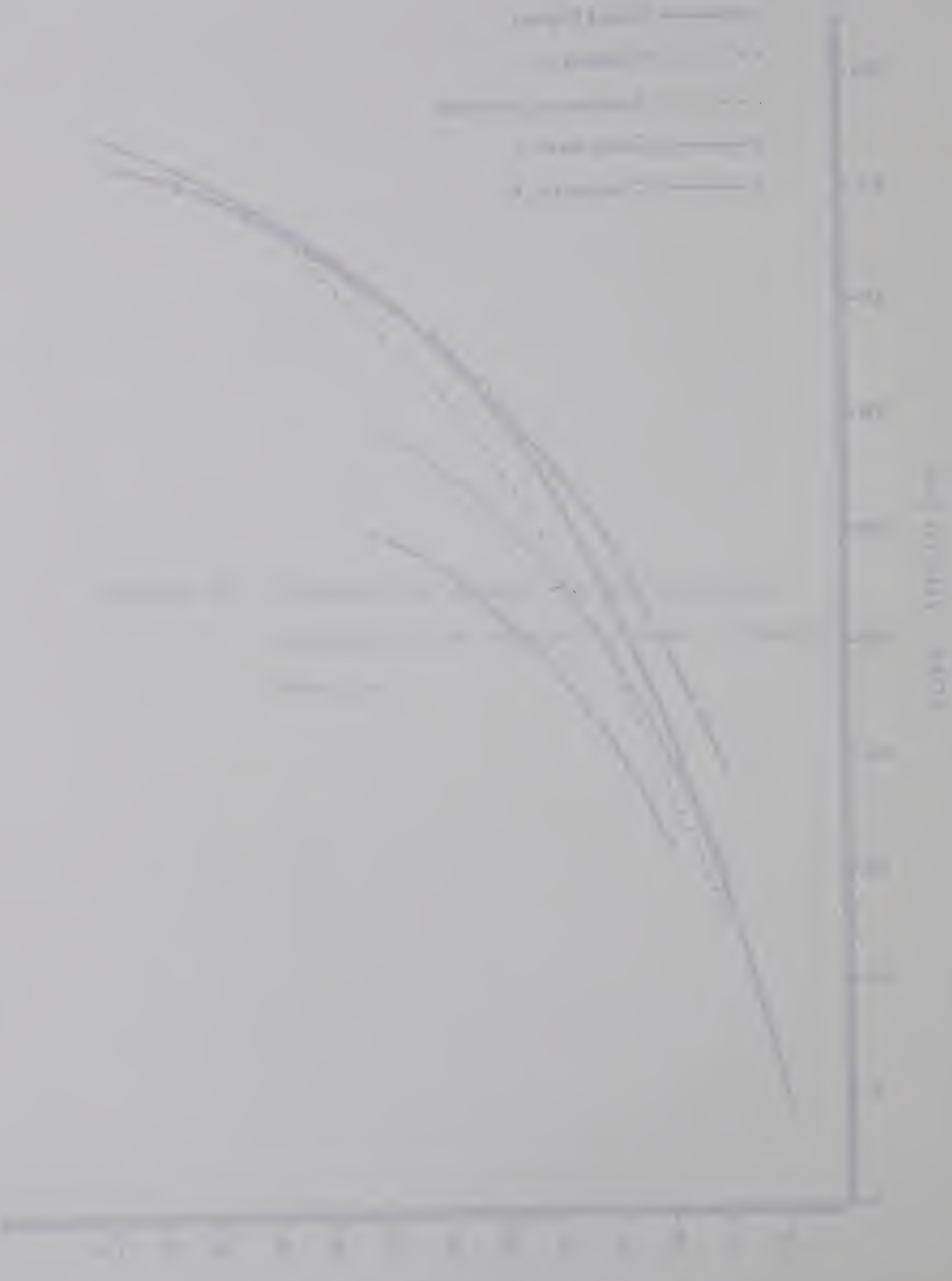
Table XVII. Average Fork Lengths and Weights at Capture of Grayling from Various Sources

	Miller: Great Bear Lake			Ward: Athabaska Drainage			Schallock: Chatanika R. Alaska		Reed: Fielding Lake, Alaska		
Age	no. specimens	av. fork length (mm)	av. weight (oz)	no. specimens	av. fork length (mm)	av. weight (oz)	no. specimens	av. length	no. specimens	length males	length females
1	1	196	2.5	13	148.8	1.9	--	--	--	--	--
2	3	272	7.5	15	202.8	3.4	50	162.6	8	188.0	192.0
3	14	290	9.4	54	240.4	5.6	50	208.3	29	229.0	227.2
4	18	317	13.4	75	283.2	8.6	50	241.3	3	--	267.0
5	17	356	18.2	32	307.7	15.7	50	261.6	6	328.3	317.0
6	17	374	21.8	16	338.3	16.0	9	281.9	26	370.6	360.8
7	16	393	23.8	2	337.5	16.2	2	297.2	21	401.6	384.5
8	6	413	27.8	--	--	--	--	--	7	427.0	415.6
9	5	425	32.7	--	--	--	--	--	--	--	--
10	2	436	37.1	--	--	--	--	--	--	--	--
11	1	462	45.5	--	--	--	--	--	--	--	--

Figure 27. Comparative growth curves of Arctic grayling from various sources in North America.



Great Slave L.
Fielding L.
Athabaska Drainage
Great Bear L.
Chatanika R.
FORK LENGTH (cm)
50
45
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
9
10
11
12
AGE
(years)



in similar age groups from Great Slave Lake up to age seven. From age seven to eleven, Great Bear Lake grayling are slightly smaller than Great Slave Lake fish. Miller's comparison with calculated growth rates between Great Slave Lake and Great Bear Lake grayling showed that the Great Slave Lake grayling grow faster in all age groups (Miller, 1946).

Grayling from the Athabaska drainage in Alberta are the same size as grayling from Great Slave Lake at age one. From age two to seven the Alberta fish decrease steadily in size as compared to the Great Slave Lake grayling (Ward, 1951).

A comparison of the Alaska grayling shows that the Chatanika River grayling grow at a slower rate than do any of the other grayling from the other locations [Schallock, n.d.].

The Fielding Lake grayling approach the growth rate of the Great Slave Lake fish most closely at age one and age eight, but always they are smaller fish than the Great Slave Lake grayling (Reed, 1964).

Information on the Montana grayling (_T_. _signifer_ _tricolor_) shows that this subspecies of Arctic grayling grows faster than the Great Slave Lake grayling for about the first four years of life but it does not live much past five years (Nelson, 1943; Brown, 1943).

In summary, it can be said that the grayling from Great Slave Lake and Great Bear Lake appear to grow at similar rates with Great Bear Lake grayling being slightly

larger in the first years of life but after seven years falling slightly behind the fish of Great Slave Lake. The fish from Alberta and Alaska grow at slower rates of growth than do the Great Slave Lake grayling. Grayling from Great Slave Lake apparently grow slower than grayling of Montana but they live longer than the Montana fish.

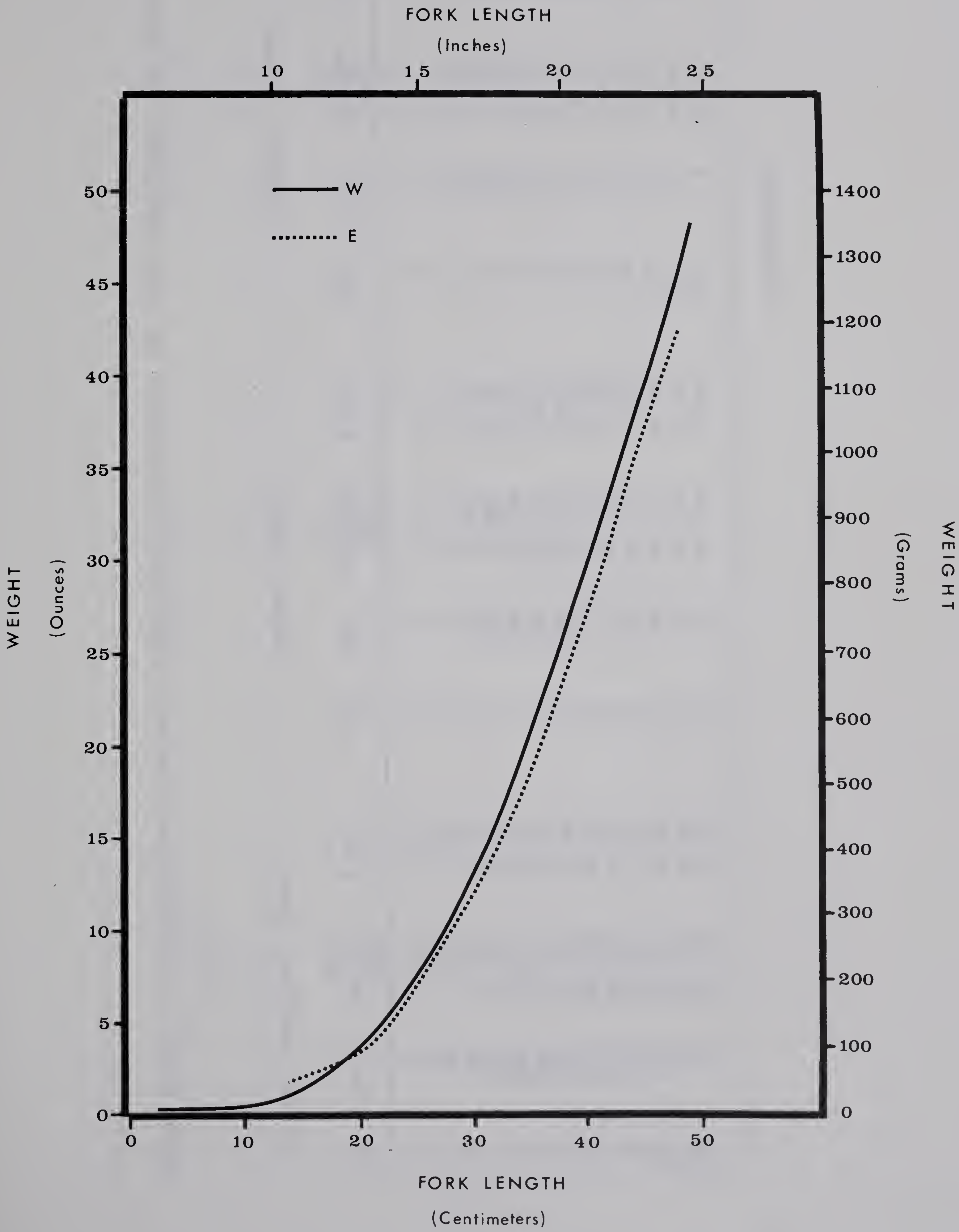
It would seem that the conditions of Great Slave Lake are very nearly ideal for Arctic grayling, as they live longer and grow larger than Arctic grayling from any other areas in North America, with the possible exception of Great Bear Lake.

e. Growth curves (weight)

As would be expected from the length data on rates of growth and the growth curves, the grayling from the West are only slightly heavier in all age groups than are the grayling from the East (Fig. 28, Table XVIII). In the eastern part of the lake males are heavier than females from age 2 to age 12; from age 9 to age 11, the males are heavier by about 3 ounces (Fig. 29). Although the weights of both sexes appear equal at age 12, this is probably due to the small sample involved (13). In the western part of the lake, the weights of both sexes are very close, at least up to age 6 and even then the males are only slightly heavier than the females (Fig. 30). No females were found older than 10 years in the West so no comparison can be made past this age.

Grayling from the East and West of the same length have

Figure 28. Length-weight relationship between the East and West grayling (sexes combined).


FORK LENGTH
(Inches)
10
15
20
25
W
E
50
45
40
35
30
25
20
15
10
5
0
WEIGHT
(Ounces)
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
WEIGHT
(Grams)
0
10
20
30
40
50
FORK LENGTH
(Centimeters)

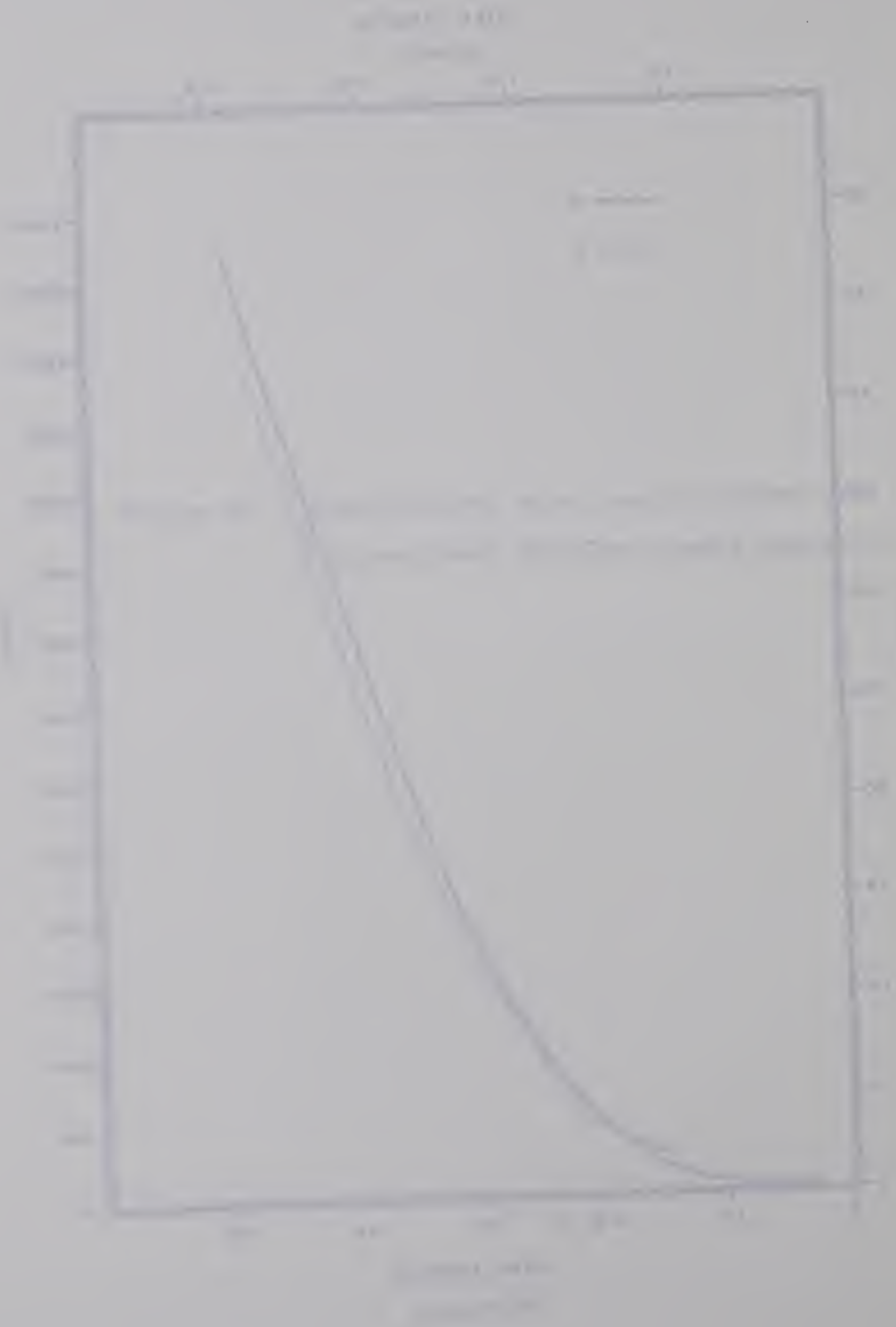


Table XVIII. Averages and standard deviations of weights of 2493 grayling, age groups 0-12.

Sexes combined (East)				Males (East)				Females (East)			
Age	No.	Av. Weight (oz)	S.D.	Age	No.	Av. Weight (oz)	S.D.	Age	No.	Av. Weight (oz)	S.D.
0	5	.05	.01	0	-	-	-	0	-	-	-
1	8	.3	.06	1	-	-	-	1	-	-	-
2	84	3.82	1.51	2	42	3.91	1.25	2	32	4.09	1.80
3	92	8.36	2.79	3	50	8.84	3.22	3	40	7.80	2.12
4	146	12.14	2.93	4	80	12.24	2.92	4	64	12.09	2.89
5	280	17.59	4.22	5	137	18.13	4.03	5	143	17.08	4.35
6	194	21.55	3.56	6	100	22.40	3.62	6	92	20.62	3.31
7	147	26.19	4.19	7	73	26.75	4.22	7	74	25.65	4.13
8	149	29.66	3.99	8	52	30.52	2.85	8	97	29.21	4.44
9	108	33.69	5.03	9	36	36.14	6.02	9	72	32.46	3.95
10	61	35.03	4.48	10	34	36.59	4.34	10	27	33.07	3.90
11	35	36.26	4.85	11	20	37.30	5.12	11	15	34.87	4.24
12	13	40.15	4.39	12	10	40.20	3.49	12	3	40.00	7.81

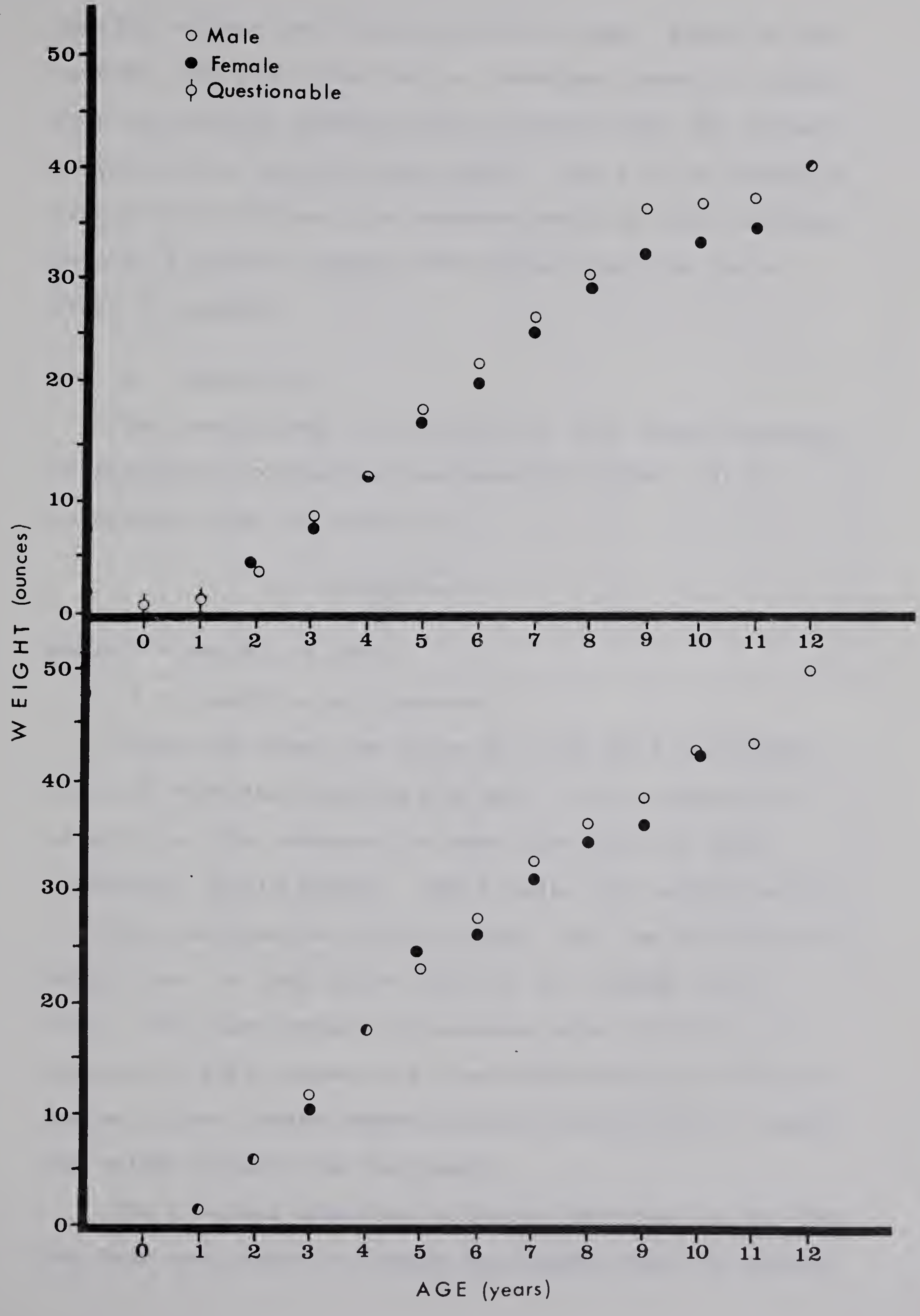
continued

Table XVIII. Continued.

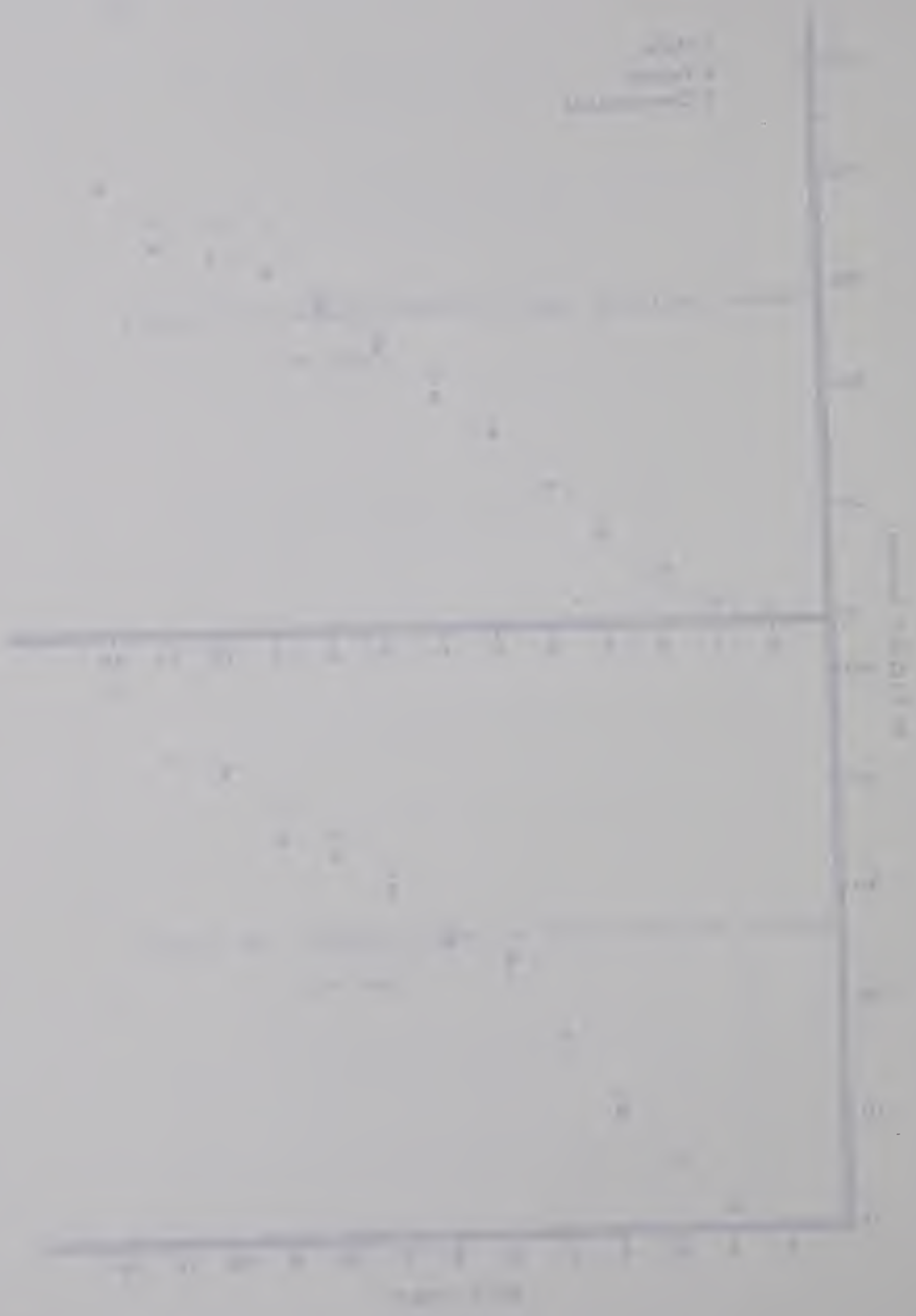
Sexes combined (West)				Males (West)				Females (West)			
Age	No.	Av. Weight (oz)	S.D.	Age	No.	Av. Weight (oz)	S.D.	Age	No.	Av. Weight (oz)	S.D.
0	51	.05	.01	0	-	-	-	0	-	-	-
1	18	1.78	0.65	1	3	1.67	0.58	1	7	1.86	.69
2	46	5.78	1.28	2	24	5.96	1.29	2	18	5.67	1.33
3	71	11.34	2.35	3	39	11.79	2.51	3	31	10.81	2.09
4	46	17.30	3.74	4	32	17.06	3.54	4	14	17.86	4.26
5	62	23.90	3.83	5	38	23.82	4.20	5	24	24.04	3.22
6	158	26.98	4.43	6	85	27.79	4.27	6	73	26.04	4.45
7	192	32.23	4.49	7	106	32.95	4.69	7	85	31.37	4.09
8	291	36.15	4.59	8	198	36.79	4.41	8	90	34.61	4.63
9	183	38.06	5.31	9	148	38.59	4.74	9	35	35.77	6.86
10	40	41.58	8.14	10	33	42.69	5.12	10	6	42.17	3.31
11	8	43.38	4.21	11	8	43.38	4.21	11	-	-	-
12	4	48.00	4.89	12	3	50.00	3.46	12	-	-	-

Figure 29. Growth curves of East grayling (weight vs age).

Figure 30. Growth curves of West grayling (weight vs age).



Male
Female
Questionable
WEIGHT (ounces)
AGE (years)
0
10
20
30
40
50
0 1 2 3 4 5 6 7 8 9 10 11 12



similar weights for fish up to 30 cm long. After 30 cm, however, the fish from the two locations start to differ, with the western grayling being heavier than the eastern grayling (Fig. 28 and Table XVII). For a 10 cm change in length (30 to 40 cm), the eastern grayling gains approximately 15 ounces, whereas the western grayling gains about 17 ounces.

f. Condition

The coefficient of condition k, is a direct measure of plumpness or relative heaviness of a fish. It is calculated from the equation:

$$k = \frac{W \times 10^5}{L^3}$$

where W = weight in grams

L = length in millimeters

Table XIX shows the value of k for male and female grayling from the East and the West. The lengths and weights are the averages for each age group as shown previously (Table XVIII). The k value for eastern males (1.1645) and females (1.1834) shows that the two sexes are very close, as they differ only in the second decimal place. The same values for western males (1.2702) and females (1.2765) shows that they differ only in the third decimal place, again emphasizing the similarity in length and weight between the two sexes.

The k values show that although the males in the East and West are larger in length and weight than the females

Table XIX. Value of k in Formula $k = \frac{W \times 10^5}{L^3}$ Based on Length and Weight Averages of Different Age Groups of Grayling in G.S.L.

Age Group	Males					Females				
	No. of specimens	Av. length (mm)	Weight		k	No. of specimens	Av. length (mm)	Weight		k
			oz.	gm.				oz.	gm.	
East										
0	--	--	--	--	--	--	--	--	--	--
1	--	--	--	--	--	--	--	--	--	--
2	42	210	3.9	111	1.1942	32	211	4.1	116	1.2369
3	50	270	8.8	250	1.2675	40	263	7.8	221	1.2154
4	80	305	12.2	346	1.2191	64	303	12.1	343	1.2330
5	137	349	18.1	513	1.2070	143	341	17.1	485	1.2226
6	100	378	22.4	635	1.1757	92	367	20.6	584	1.1814
7	73	401	26.7	757	1.1738	74	394	25.6	726	1.1866
8	52	425	30.5	865	1.1264	97	413	29.2	828	1.1751
9	36	447	36.1	1023	1.1458	72	432	32.5	921	1.1428
10	34	445	36.6	1038	1.1015	27	432	33.1	938	1.1639
11	20	457	37.3	1058	1.1079	15	440	34.9	989	1.1614
12	10	471	40.2	1140	1.0906	3	469	40.0	1134	1.0992
Average					1.1645					1.1834
West										
0	--	--	--	--	--	--	--	--	--	--
1	3	161	1.7	48	1.1549	7	165	1.8	51	1.1353
2	24	236	6.0	170	1.2941	18	228	5.7	162	1.3626
3	39	294	11.8	335	1.3163	31	285	10.8	306	1.3227
4	32	332	17.1	485	1.3247	14	336	17.8	505	1.3302
5	38	367	23.8	675	1.3649	24	369	24.0	680	1.3542
6	85	393	27.8	788	1.2983	73	382	26.0	737	1.3223
7	106	419	32.9	933	1.2678	85	412	31.4	890	1.2729
8	198	441	36.8	1043	1.2164	90	430	34.6	981	1.2337
9	148	450	38.6	1094	1.2008	35	435	35.8	1015	1.2329
10	33	466	49.7	1409	1.3922	6	464	42.2	1196	1.1976
11	8	469	43.4	1230	1.1926	--	--	--	--	--
12	3	488	50.0	1418	1.2197	--	--	--	--	--
Average					1.1270					1.2765

of the same age group, the females in most cases, are plumper.

In Table XX, the sex is disregarded and the resulting averages for k are plotted in Fig. 31. Again it can be seen that the fish from the West are relatively heavier or plumper than the fish from the same age group from the East. It is apparent that in both ends of the lake there is a great change in length and weight in the grayling in the 0 to 1 year age group. Thereafter, the increase in weight and length in the western fish is more gradual and close to uniformity up to age 5, where after this age there is a slight decrease signifying a greater growth in length with relatively less weight being added on (Fig. 31). The eastern grayling continues to grow very fast, putting on much weight up to age two and thereafter showing a gradual decrease as less weight is put on in relation to the length.

In conclusion it appears that from the k values shown, the Arctic grayling of the Mackenzie River area is in better "condition" than the grayling from the same age group in the East part of Great Slave Lake.

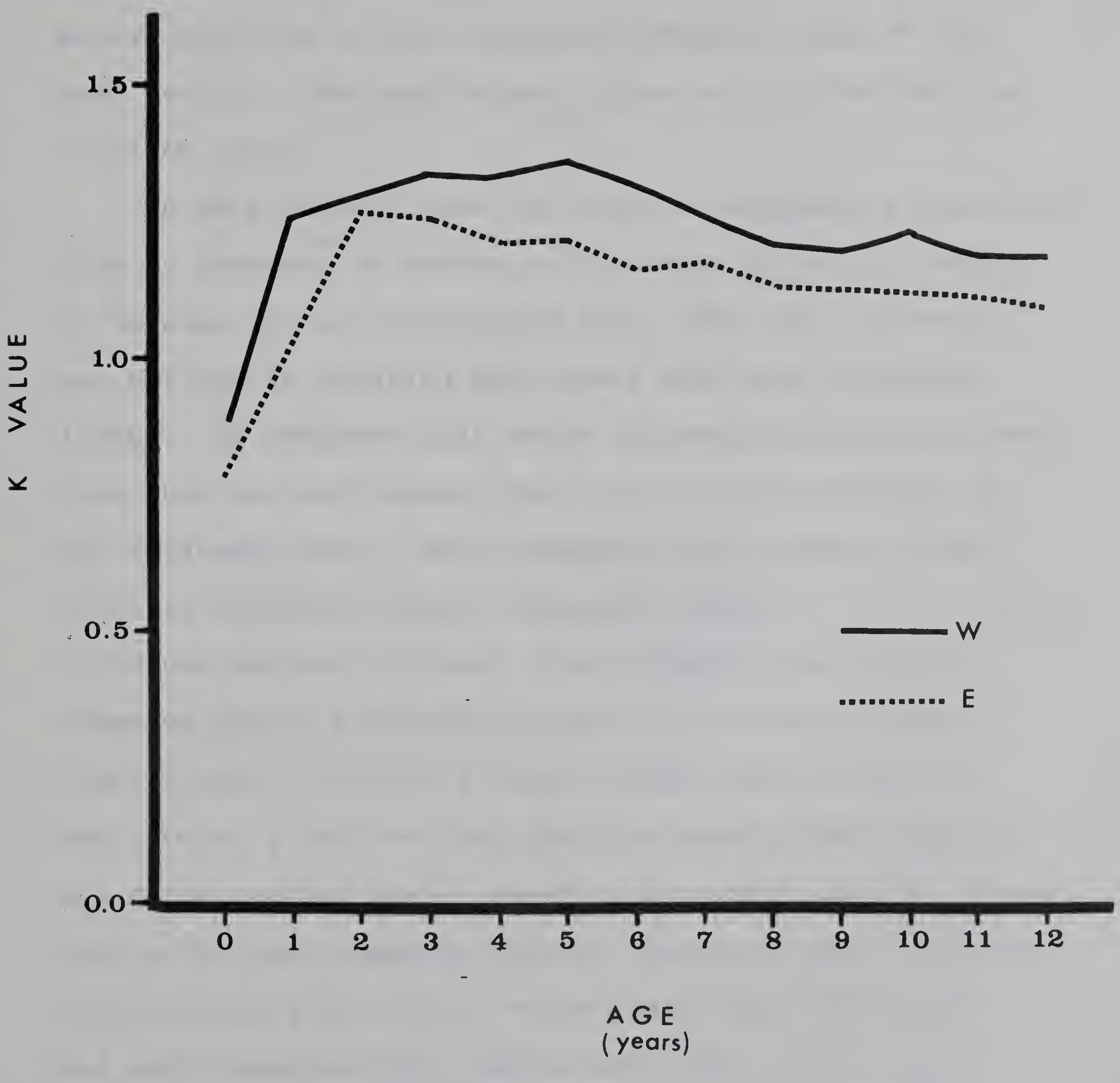
4. Age at maturity

In sexually immature Arctic grayling the testes are narrow, thin, flat strands of reddish tissue lying along the dorsal wall of the body cavity. The ovaries are similar in position and in appearance, being red and thin. The minute eggs can usually be seen by the naked eye.

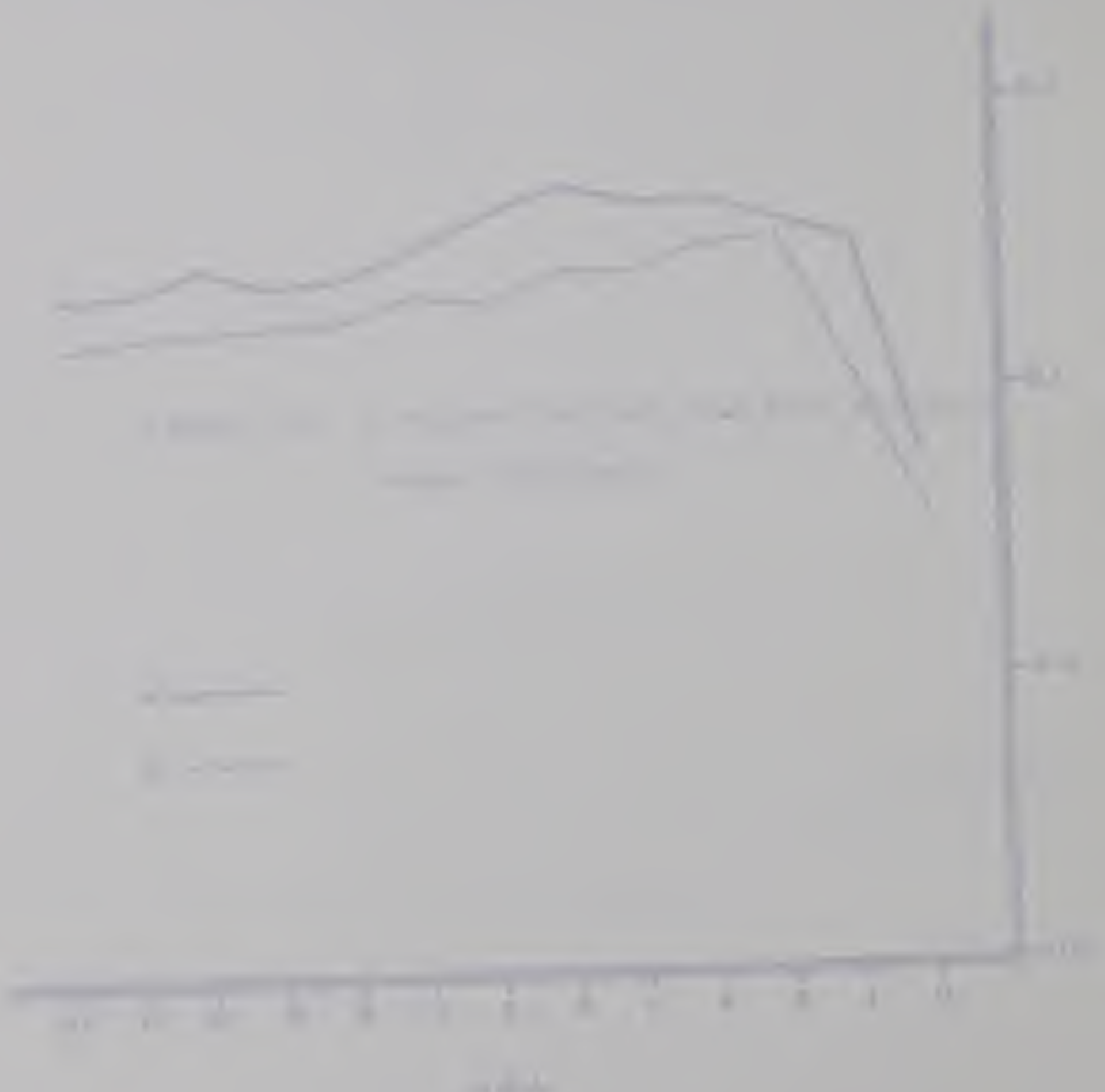
Table XX. Value of k in the Formula $k = \frac{W \times 10^5}{L^3}$ Based on Length and Weight Averages of Different Age Groups (Sexes Combined)

	EAST					WEST				
Age Group	No. of specimens	Av. length (mm)	Weight		k	No. of specimens	Av. length (mm)	Weight		k
			oz.	gm.				oz.	gm.	
0	5	56	.05	1.4	.7972	51	25	.05	1.4	.8974
1	8	95	.30	9.4	1.0547	18	159	1.8	51	1.2687
2	84	205	3.8	108	1.2570	46	233	5.8	164	1.2996
3	92	267	8.4	238	1.2509	71	290	11.3	323	1.3251
4	146	304	12.1	343	1.2208	46	333	17.3	491	1.3283
5	280	345	17.6	499	1.2149	62	368	23.9	673	1.3596
6	194	373	21.5	609	1.1744	158	388	27.0	763	1.3055
7	147	397	26.2	743	1.1871	192	416	32.2	913	1.2680
8	149	417	29.7	842	1.1611	291	438	36.1	1023	1.2179
9	108	437	33.7	955	1.1527	183	447	38.1	1080	1.2012
10	61	445	35.0	992	1.1259	40	457	41.6	1179	1.2356
11	35	450	36.3	1029	1.1293	8	470	43.4	1230	1.1850
12	13	470	40.2	1140	1.0907	4	486	48.0	1361	1.1854
Average	----------------------				1.0767	----------------------				1.2290

Figure 31. k values for East and West grayling (sexes combined).



1.5
1.0
0.5
0.0
K VALUE
0
1
2
3
4
5
6
7
8
9
10
11
12
AGE
(years)
W
E



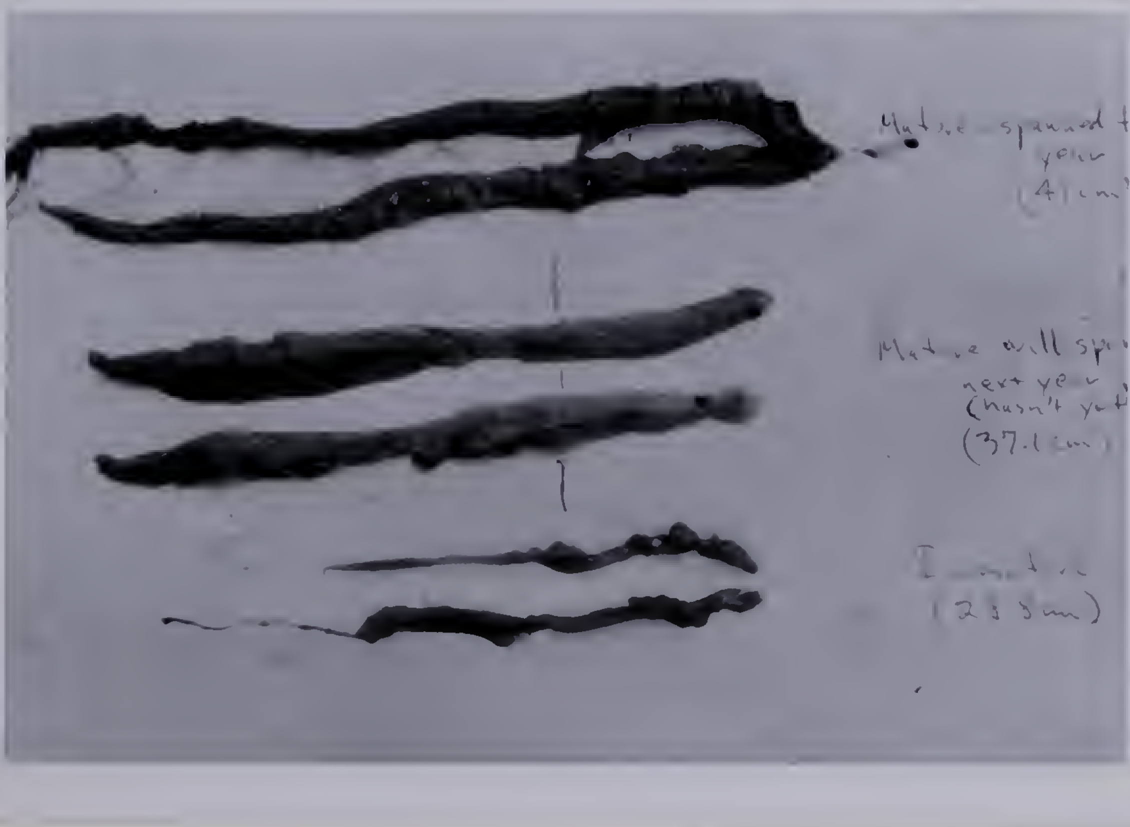
The sexually mature male grayling has large, full testes, which are white in color (Fig. 32). At the spawning period the testes swell to their full size and take up most of the unoccupied space in the body cavity. They often take on a pink-streaked appearance due to hyperemia, just before spawning begins. The ovary in a mature grayling is also large and occupies much of the body cavity. The eggs become larger in size and take on a yellow color.

In many cases it was not easy to designate a particular fish as immature or mature as it seemed to be at a stage in between the two classifications. The same condition was noticed in grayling from Great Bear Lake by Miller (1946). He proposed that these intermediate grayling were fish that had not spawned that year but who would do so the following year. This situation also exists in lake trout in northern regions (Kennedy, 1954). As I did not see any of these "questionable" fish in the spawning run at Providence Creek and as most of these "questionable" fish were found in the four to six year age groups, I believe that they are merely fish that have not quite reached sexual maturity but which will be mature before the next spawning season. Males in this "questionable" category had small, white testes and the females had small eggs and the ovaries were more of an orange color (Fig. 33).

It would appear from the data that grayling from the East mature at a slightly slower rate than do grayling

Figure 32. Grayling testes. Top pair are testes in ripe spawning condition. Middle pair are testes from a fish that has spawned at least once. Bottom pair are from a spent grayling.

Figure 33. Grayling ovaries. Top pair are ovaries from a mature fish. Middle pair are from a "questionable" fish. Bottom pair are from an immature grayling.



Mature spawned t
year
(41 cm)
Mature will spa
next year
(hasn't yet
(37.1 cm)
Immature
(28.8 cm)

from the West (Table XXI and Figure 34). At age six, in the East, approximately 80.4 per cent of the fish are mature and 9.3 per cent are immature with the remainder (10.3 per cent) being "questionable". Similar figures are obtained from the West with 94.9 per cent being mature, and 5.1 per cent being immature. By age seven, most of the grayling in both the East and the West are mature.

Some grayling from the West appear to become sexually mature at age three when they are about 33 cm long. By age six most are mature. In contrast, the grayling from the East mature slightly slower. They start to become sexually mature at age 5 when they are about 34 cm in length, and most fish are mature by age seven. The spawning run of 1966 at Providence Creek showed that 95.8 per cent of the fish caught were mature individuals of age six or over.

Rawson (1950b) reported that the spawning run of Arctic grayling in Saskatchewan was made up of fish five and six years old. Ward (1951), found that the Arctic grayling in Alberta start reaching sexual maturity at three years. Most of them were mature by five years (Miller, 1946). Maturity is reached in the third year in the Montana grayling (Brown, 1938b) and also in the grayling in Wyoming (Kruse, 1959).

It seems then, that there is a relationship between how long a fish lives and how old they are before they mature. Grayling in Great Slave Lake can reach an age of at least 12 years (one individual was found which could

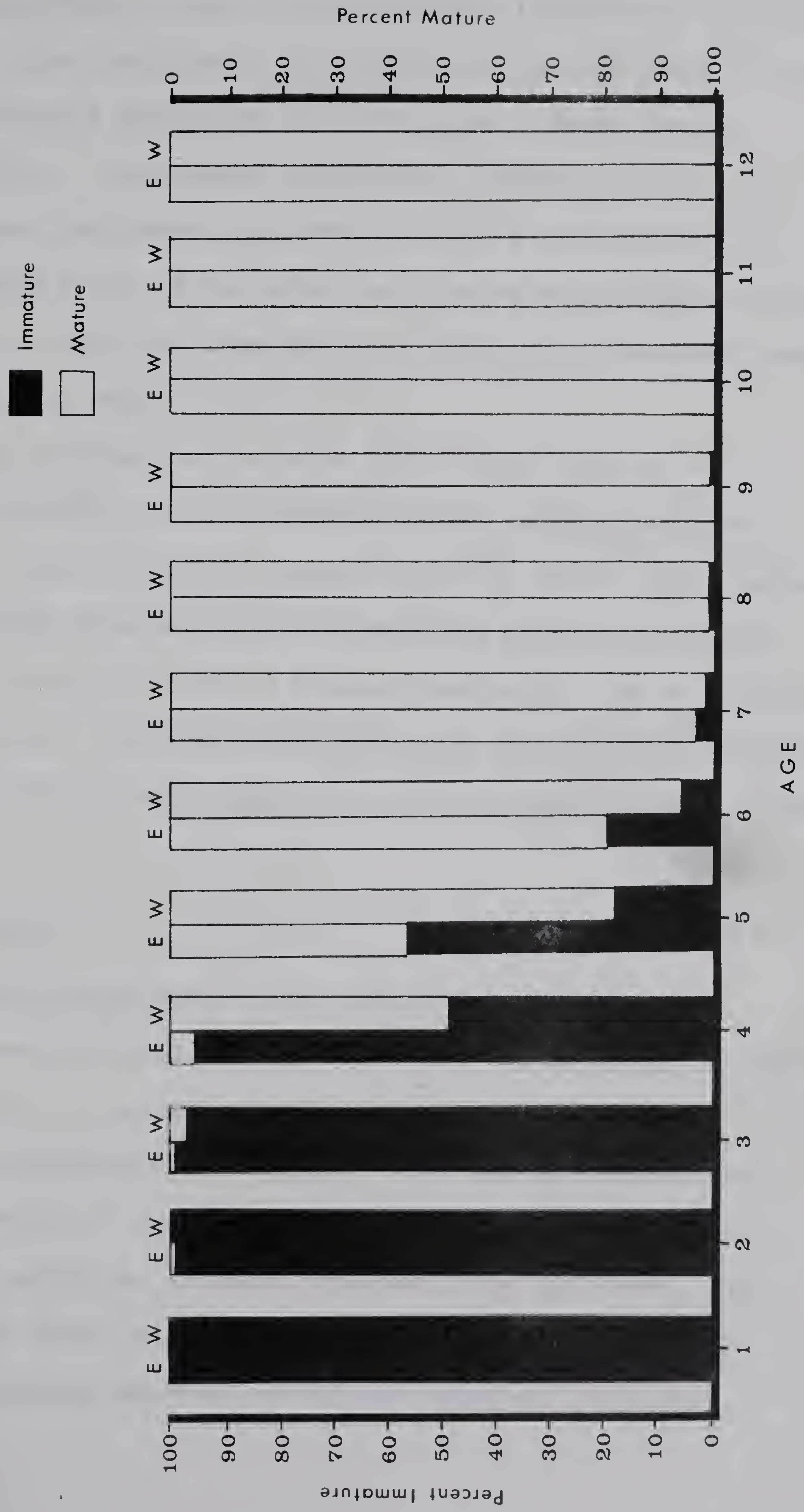
Table XXI. Relative Abundance of Immature, Sexually Mature and Questionable Grayling in 1965 and 1966

Location	Age Group 1			2			3			4			5			6		
	Imm	Mat	Ques	Imm	Mat	Ques	Imm	Mat	Ques	Imm	Mat	Ques	Imm	Mat	Ques	Imm	Mat	Ques
Number	1	0	0	72	1	11	82	1	9	104	7	35	81	121	78	18	156	20
East																		
Per Cent	100	0	0	86	.2	13	89	.1	9.8	71	4.8	24	29	43	28	9.3	80	10
Number	10	0	8	42	0	4	54	2	15	20	19	7	9	51	2	8	150	0
West																		
Per Cent	56	0	44	91	0	9	77	2.4	21	44	41	15	15	83	3.2	5.1	95	0

Location	Age Group 7			8			9			10			11			12		
	Imm	Mat	Ques	Imm	Mat	Ques	Imm	Mat	Ques	Imm	Mat	Ques	Imm	Mat	Ques	Imm	Mat	Ques
Number	1	43	3	0	148	1	0	108	0	0	61	0	0	35	0	0	13	0
East																		
Per Cent	.6	97	2.1	0	99	.7	0	100	0	0	100	0	0	100	0	0	100	0
Number	2	189	1	2	286	3	1	182	0	0	40	0	0	8	0	0	4	0
West																		
Per Cent	1	98	.6	.7	98	1	.6	99	0	0	100	0	0	100	0	0	100	0

Figure 34. Per cent immature* and per cent mature grayling for the East and the West locations (1965 and 1966).

* "questionables" are grouped with immatures.


Percent Mature
Percent Immature
Immature
Mature
AGE
E W
1
2
3
4
5
6
7
8
9
10
11
12
0
10
20
30
40
50
60
70
80
90
100

have been 13 years old) and they mature, as mentioned, around six years of age. The grayling in Alberta do not appear to grow much past five years of age and they correspondingly mature at an early age - three years (Ward, 1951). Similarly, the oldest grayling from Montana was six years old (Brown, 1943), and Kruse (1959) found none of his grayling living past three or four years old. Grayling from both of these areas matured around three years of age.

It is interesting to note that there were 61 ten-year old grayling, 35 eleven-year olds and 13 twelve-year olds taken from the eastern part of Great Slave Lake. Corresponding figures from the western part of the lake were - 40 ten-year olds, 8 eleven-year olds, and 4 twelve-year old fish. This may indicate that the eastern grayling matures slightly later than the western grayling and lives longer.

5. Parasites

A visual examination for parasites, internal and external, was carried out on about two dozen grayling while in the field. A close watch was kept for external parasites throughout the study. Very few parasites were found but many of the fish had cysts on the stomach wall. Out of 104 grayling stomachs checked from the East, 61% of them had cysts on the stomach. In the West, 53% of the 105 grayling checked contained infected stomachs.

About one dozen grayling, plus samples of parasites found in the field, were turned over to Dr. D. D. Anthony and Mr. R. B. Podesta of the University of Alberta, Edmonton, for further identification and further study.

The cysts on the stomach walls of the grayling were found to be larval nematode cysts which were unidentifiable because all were either immature or absorbed. The following is a list of the parasites and locations where infected fish were caught:

Hirudinea	-	<u>Illinobdella</u> sp.	(found in the Mackenzie River and Providence Creek)
Nematoda	-	<u>Raphidascaris</u> sp.	(found in the Mackenzie River and Providence Creek)
		<u>Echinorhynchus</u> sp.	(found in the Mackenzie River)
		<u>Cystidicola</u> sp.	(found in the Kakisa River)
Parasitic Copepoda	-	<u>Salmincola</u> sp.	(found in Providence Creek)

No <u>Triaenophorus</u> cysts were found.

VI. MODE OF LIFE AND BEHAVIOR

1. Spawning of Providence Creek grayling

a. Introduction

The spawning of the grayling in Great Slave Lake and surrounding areas takes place during spring - April to May. This spawning period correspond with the break-up of the ice in the rivers.

Grayling are known to spawn in two areas near the town of Hay River. The biggest run is in the Kakisa River where the fish become concentrated at Lady Evelyn Falls. The fish cannot ascend the 46-foot high falls and consequently spawning grayling can often be caught at the base of the falls. The other location is Providence Creek.

The latter location was chosen as the study site for the spawning of grayling because of its practical size, easy accessibility, and because grayling were reported to enter it in large numbers during spawning season.

In 1965 grayling were reported as being caught as early as April 16 in the Kakisa River at Lady Evelyn Falls when the river was only partially opened up. In 1966 the break-up of Kakisa River came a little later, on April 30. A grayling caught at the Falls this same day was a male in spawning condition.

Providence Creek remained frozen to the bottom until May 7, 1966, when it first started to flow steadily. The stream flows into the Mackenzie River a few hundred feet downstream from the study site. As the Mackenzie River was still frozen

over, the first flowing water from the creek disappeared through a hole in the ice (Fig. 35). On May 9, a pike and three grayling were seen near the study site and it was obvious that they had entered the creek by jumping up through the hole in the ice. Another grayling was found lying on the ice on the Mackenzie River near another hole. It is evident that the grayling were waiting under the ice for the creek to open up.

This close association of the ice break-up and the spawning migration of the grayling has been noted by other authors (Brown, 1938b; Rawson, 1950; Reed, 1964; Schallock, n.d.). It seems that the grayling migrate from the lakes and larger streams to the smaller tributaries which are the first to become free of ice. They appear to move upstream as soon as the ice starts to move. They are in spawning condition by this time.

In Providence Creek there were both pike and grayling spawning at the same time in the same area. Although the spawning act of the pike was never seen, it seemed that the main run of pike came a little before the main run of grayling. In the Kakisa River, pike, grayling, walleye, and longnose suckers were all caught by angling in the spring. All species were in spawning condition.

An attempt was made to use a fyke net in the creek but the combined force of the current and the floating debris made it impossible. All fish caught in Providence Creek were caught either by angling or in a 5-inch gill net. There seemed to be a definite bias depending on which method was used to catch

Figure 35. The mouth of Providence Creek showing the water disappearing through the hole in the ice. Mackenzie River in background. Early May, 1966.

Figure 36. Method of observing grayling in Providence Creek, using glass-bottomed viewing box. Note riffle where feeding grayling were found. Spawning area further downstream.

the grayling. The angling method tended to take smaller fish, whereas the gill net took more of the larger fish. This was found to be the general case throughout the whole study. As can be seen from Figure 37 the larger fish of the sample were males. The male to female ratio was 1.3:1 This difference from the expected ratio is not statistically significant.

Brown (1938b) found a sex ratio of 3:1 in the Montana grayling run in favor of the males. In Alberta the ratio was three males to one female in the early part of the run but this changed to a 5:1 ratio in favor of the females later on (Ward, 1951). Kruse (1959) found a ratio of 1:1 in the Grebe Lake, Montana, spawning run.

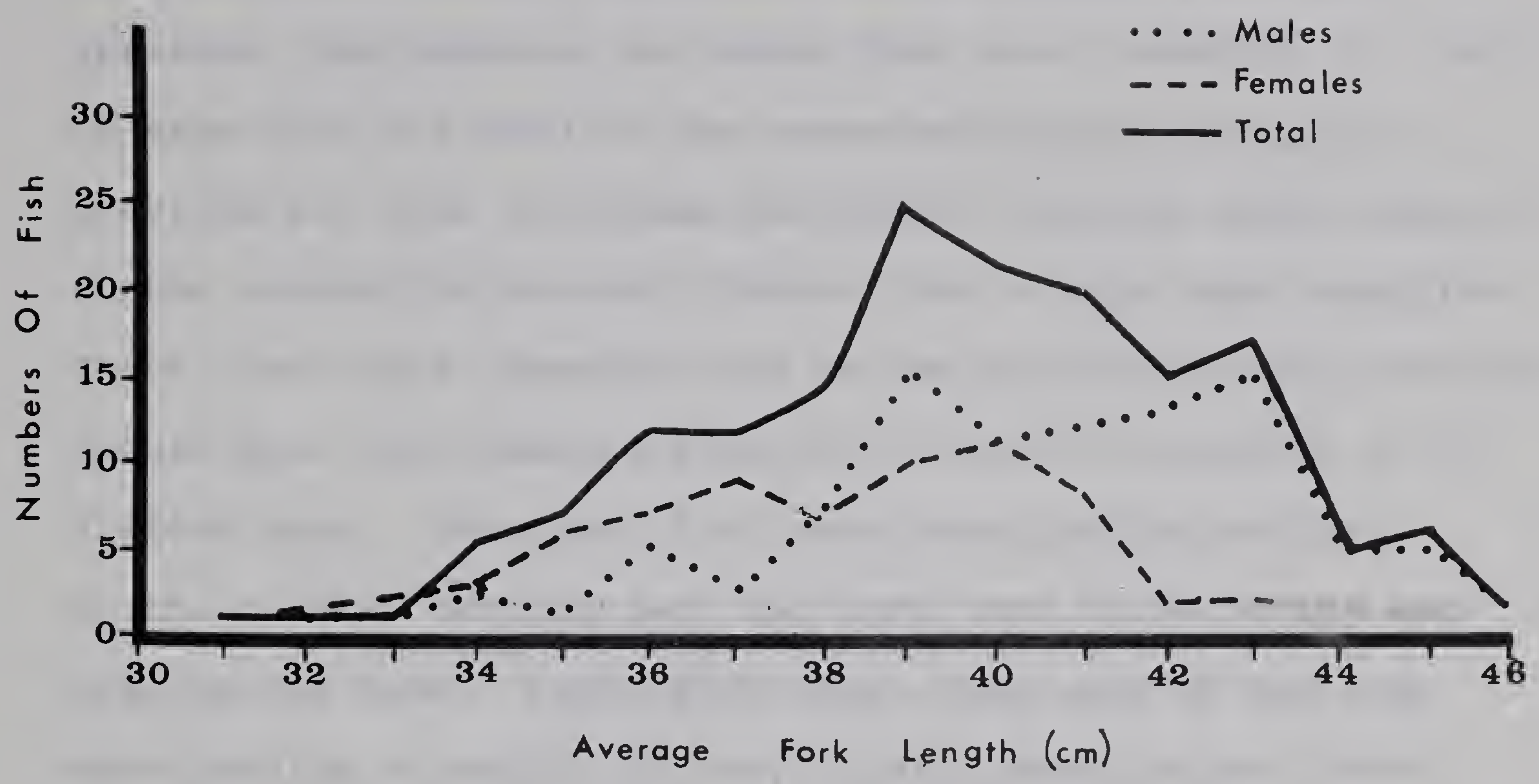
Figure 38 shows the age composition of the spawning run in 1966. Fish in the six to nine year group make up 93.5 % of the run. Of the 1968 grayling caught in the spawning run, only 7 were non-spawning fish. Of these, five were immature fish and the other two were labelled "questionable" as to whether they were mature or not. From this sample it appears that the grayling spawns every year.

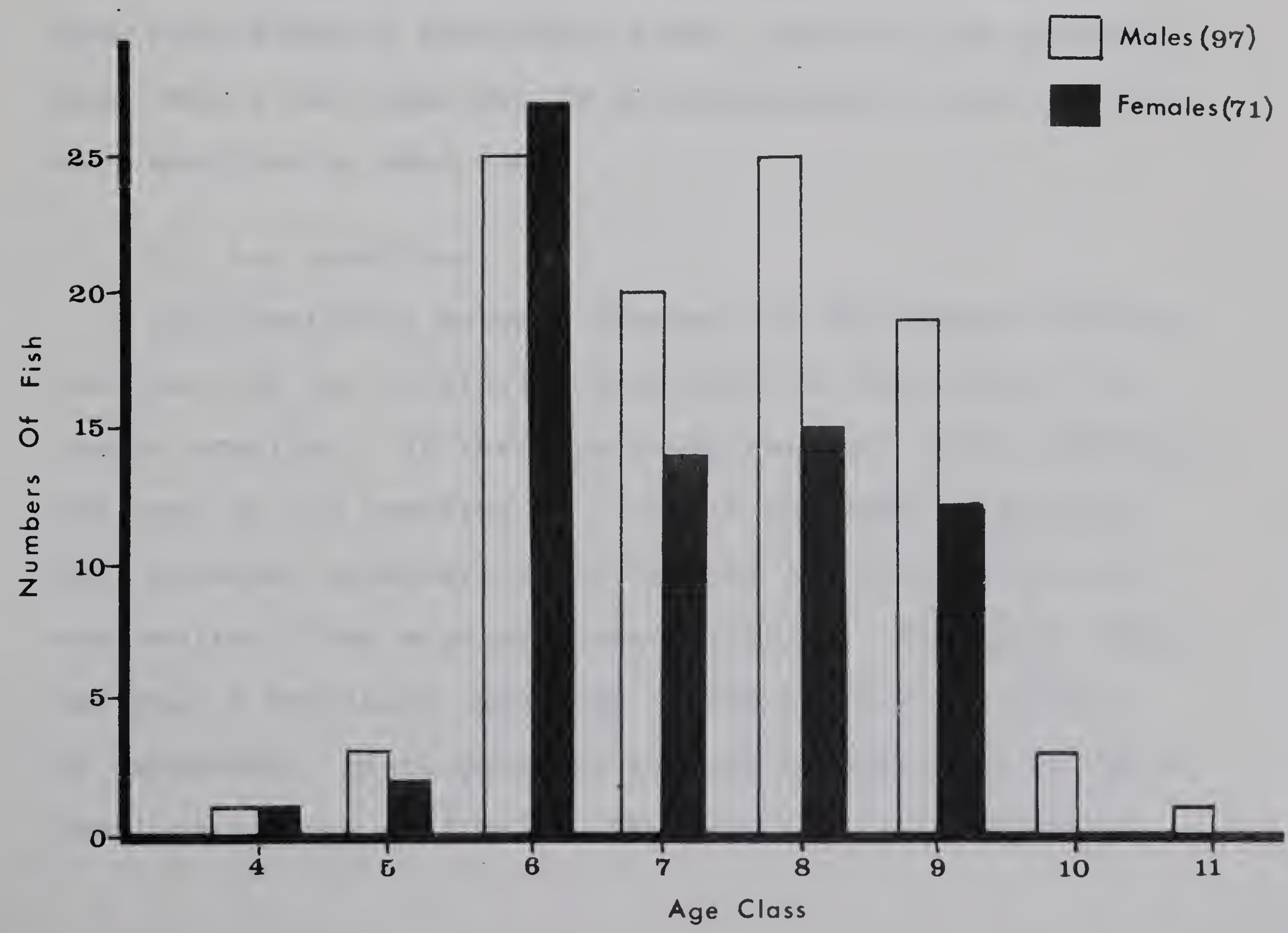
b. Feeding activity

The fish seemed to feed all through the spawning period, but there was a definite distinction in the way that they fed. Before the fish had spawned they fed only incidentally and did not go out of their way to get food. After they had finished spawning, many of the fish moved to a small riffle upstream from the spawning area and there they fed actively. This was substantiated in a number of ways.

Figure 37. Length-frequency diagram of the Providence Creek spawning run, 1966.

Figure 38. Age composition of the Providence Creek spawning run, 1966.


Males
Females
Total
Numbers Of Fish
0
5
10
15
20
25
30
30
32
34
36
38
40
42
44
46
Average Fork Length (cm)


Males (97)
Females (71)
Numbers Of Fish
0
5
10
15
20
25
4
5
6
7
8
9
10
11
Age Class

First, all the fish caught by angling (66) were spent fish; not once was a ripe unspawned fish caught by the hook-and-line method. Second, when the stomach contents of the spawning, pre-spawning and spent fish were compared, it could be seen that the food of the pre-spawning and spawning grayling was less in volume and better digested when compared to the greater volume and fresher food of the spent grayling. Third, the visual observations on the activity of the grayling showed that the spawning fish only took food casually as it drifted past. The spent fish were seen feeding actively in the riffle, darting back and forth and manoeuvering constantly for food. Table XXVI shows that many of the fish were feeding on mayfly larvae, chiefly Baetidae and other insects. Baetid larvae were the single most important food item found in Providence Creek. Many of the grayling were eating fish eggs but it was impossible to tell if they were grayling or pike eggs.

c. Sex condition

Distinguishing between spawned and pre-spawned individuals was not too difficult, especially in the case of the female grayling. In the ripe condition just before spawning, the eggs of the grayling [illegible] run if the body is squeezed. Upon internal examination the ovaries are seen to be large and swollen. The eggs are orange-colored. The spent female has only a few large eggs left in the ovary which cannot be expressed. Distinguishing the sex condition in the male grayling is more difficult. The ripe testis is large and

swollen and quite milky-looking. (Fig. 32). An interesting point here is that a ripe male releases very little milt when the body is squeezed. This fact has been mentioned by other investigators who have worked with the spawning of grayling in other locations (Brown, 1938b; Rawson, 1950b; Ward, 1951). A male which has spawned will have varying degrees of redness showing in the testis depending on how many times he has spawned. The red color is due to the rupturing of tiny blood vessels.

There was no way to say how many times a particular grayling caught in Providence Creek had spawned. Ward (1951) found that he could use his males up to three times if he left them for a day or two, between expressing milt. Fabricius and Gustafson (1955) saw one male of T. thymallus which performed the spawning act 78 times, 60 of which were in one day. They also said that of three females under observation, they spawned 19, 27 and 34 times respectively in one day. Brown (1938b) mentions that he observed one female from Montana spawn twice within 45 minutes. From my own observations I believe that the female grayling in Providence Creek release most or all of their eggs in one sex act, for as near as could be ascertained, none of the females were caught with only part of their ripe eggs remaining in the ovary. They either contained their full complement of ripe eggs or they were empty. In one case where a male grayling could be distinguished from the other fish due to a torn fin and a bruised side, it was seen that this fish held a territory for two days in a row, so it could be

assumed that he was able to spawn for this length of time although it is not known how many times the spawning act was performed.

d. Fecundity

The number of eggs per female were estimated by volumetric displacement. The total was checked by actual counting in a number of cases (Table XXII). The check showed that the volumetric method underestimated thenumbers of eggs by about 7 per cent.

Table XXIV shows the number of eggs obtained from each fish that was measured. From the fifteen fish there was an average of 9,670 eggs each. This works out to 310.9 eggs per ounce of fish. This figure is lower than other worker's figures. Brown (1938b) found 357 eggs per ounce and Ward (1951) found 376 eggs per ounce. Rawson (1950b) reported only the number or eggs without the size or weight of the fish, saying that most females produced between 4000 and 7000 eggs but a few of the largest fish yielded more than 10,000 eggs each.

The diameter of fresh eggs measured 2.6 mm which compares closely to the figures of Norden (1959) who found 2.5 mm before the eggs of <u>T. arcticus</u> were water hardened. In the same species, Reed (1964) found the average diameter on 100 measurements of water hardened eggs to be 2.7 mm. The size of the American grayling <u>T. signifer tricolor</u> were found to be 2.4 mm when fresh (Watling and Brown, 1955).

Table XXII. Actual counts of eggs in ovaries.

Number	Volumetric method	Actual count	Difference
1	4050	3964	- 86
2	5603	5961	+358
3	4009	4458	+449
4	4272	4542	+270
5	6144	6469	+325

Table XXIII. Numbers of days, temperature units, and mean temperatures recorded from impregnation to hatching of the eggs.

Stage	No. of days	Mean daily temp. °C	°F	Day degrees*
Impregnation to eyed	10	8.6	47.5	155.0
Impregnation to hatching	13.7	9.1	48.4	229.6

*Number of days X °F above 32

Table XXIV. The numbers of eggs from 15 grayling taken from Providence Creek, 1966.

	Length (cm)	Weight (ozs)	Number of Eggs
1	41.9	33.5	9,919
2	38.3	30.0	12,432
3	40.1	31.5	10,010
4	39.2	31.5	8,439
5	43.2	45.0	15,905
6	40.1	33.0	9,667
7	40.3	33.0	10,780
8	36.8	24.5	7,830
9	41.3	32.0	11,247
10	25.4	24.9	7,649
11	38.5	29.0	7,293
12	39.1	30.0	6,120
13	37.4	24.5	8,496
14	40.9	34.0	12,311
15	38.0	31.0	6,952
Total	580.5	466.5	145,050
Average	38.7	31.1	9,670

Mean number of eggs per ounce of fish = 310.9

e. Egg Development

An attempt was made in 1966 to determine the period required for grayling eggs to hatch. The experiment was carried out in Providence Creek. The eggs were stripped and fertilized using the "dry" method as described by Hey (1947). The eggs were very adhesive when first stripped from the female, but the stickiness was gradually lost as the eggs became water-hardened. The eggs were incubated in pint sealers with galvanized screening over the openings. A number of jars were placed in a wooden holder and submerged in a good current of water. Two batches of eggs were fertilized in this manner but only the first batch grew successfully. There seemed to be a high per cent of fertility although no actual count was made. The eggs reached the eyed stage in about 10 days and the first egg hatched in 13 1/2 days (Table XXIII). There was a fairly high mortality during incubation. The eggs were attacked by a fungus-like growth. The average water temperature was 8.8 C and the eggs took 229.6 day degrees to hatch. This value is lower than that found by Ward (1955) and that estimate by Ward from Rawson's (1950b) data. Each of their samples hatched in about 250 Tryon (1947) obtained similar results to those of the Providence Creek experiment to the eyed stage of embryonic development, but the eggs in his experiment did not hatch for 23 days even though the water temperatures he recorded were similar to those recorded during the experiment at Providence Creek.

f. Observations on daily rhythm of activity

As mentioned earlier, the Arctic grayling has been described as showing sexual dimorphism in Saskatchewan (Rawson, 1950b) and Alaska (Wojcik, 1955). Evidence from the Great Slave Lake region shows that the grayling sexes can be distinguished by sight for most fish that are about 40 cm in length or longer. Ninety-two per cent of 308 judgements on the sex of the fish were correct.

The fish in Providence Creek did not occupy the waters at the study site throughout a 24-hour cycle, but seemed to move out at night and move back during the day. Night-time activity was checked as well as possible with the aid of a battery lantern. Never were any fish seen. Evidence from the number of fish caught overnight in gill nets indicated that most fish were caught about dusk and very few were caught during the dark. Also very few fish were seen in the morning. About 12 o'clock noon they started to move into the spawning area in large numbers. The water temperatures fluctuated very much during the day and night, as much as 5 C on some days. The presence of grayling seemed to be related to a temperature of about 8 to 10 C. Other workers also found a relation between the presence of grayling and the water temperature. Fabricius and Gustafson (1955) observed that in their stream, in the afternoon, the intensity of the spawning rose to a maximum, which was reached at the time the water was at its warmest and then it gradually decreased in the evening. They concluded that the daily rhythm of water temperatures was very marked in shallow streams and is the

most important of the stimuli affecting the timing of the rhythm of spawning and defence of territories in the grayling. The rising temperature during the day seemed to stimulate these activities. From their experiments they concluded that intense light stimulates the defence of territories and the spawning but temporarily inhibits the migration. Tryon (1947) reported that the Montana grayling slackens its spawning activities after 11:00 p.m. Most of the spawning took place in water which was about 10 C (50 F)

g. Spawning behavior

Fabricius and Gustafson (1955) made a careful study of the spawning behavior of _T_. _thymallus_. No observations of this nature have ever been made on the American grayling, although there are quite a few general observations on spawning in North America grayling. Brown (1951), Tryon (1947), and Kruse (1959), studied Montana grayling. Ward (1951) studied Athabaska drainage grayling in Alberta. Reed (1964) described spawning behavior in Alaska grayling. Most of these observations were apparently made from the banks of the stream and usually in very shallow water.

The spawning area was a deeper part of the stream just below a riffle which was used as a feeding area (Fig. 36). The water flow in this part of the stream was measured at approximately 62 cubic feet/second (current about 25 feet/sec). The depth in the deeper parts of the stream was about 3 feet and width was about 26 feet, although 8 feet of this was a very shallow sand bar in the vicinity of the spawning area.

The first thing that became apparent from observing the grayling was that the larger males were holding territories along the deeper parts of the stream. I was able to verify this observation in one case by watching a particular male that had a torn fin and a bruise on his side that distinguished him from other fish. From one period from 1:00 to 5:00 p.m., this fish was observed in the water at one particular location just behind a large rock. The next day this same fish had moved upstream about 12 feet to a new station. As closely as could be ascertained, the territory held by this fish was about 6 feet wide by 12 feet long. Fabricius and Gustafson mention that the territory-holding fish in their study were a different color, the flanks and back becoming a brownish or dark grey while the tip of the nose became white in many specimens. In Providence Creek differently colored males were seen and caught. Most of the larger males had a very dark belly, but it is not known if this was a characteristic of territory-holding fish or not.

Whenever a small fish swam into the vicinity of a fish holding a territory, the territory-holder would frighten it off by dashing at it. It the intruding fish was large, then another behavior was elicited. Both fish would raise their dorsal fins and extend their pelvic fins to their full length and would swim very close to each other, side by side (Fig. 39). The dorsal and the pelvic fins are each brightly patterned. When side by side both fish quivered rapidly. They swam toward the surface at an angle of about 30-45 degrees to the bottom.

Figure 39. Male grayling at end of display. Dorsal fin only partially erect, pelvic and pectoral fins still extended. Note typical gravel bottom.

Figure 40. Male grayling in act of "vibrating display". Note extended dorsal fin.

Both fish gaped widely throughout this display. Fabricius and Gustafson call this behavior a "mutual lateral display". They point out that individuals of T. thymallus have a white throat with a black spot on each side which is only visible when the bottom of the mouth is lowered during the height of intense mutual lateral display. Individuals of T. arcticus in Great Slave Lake also possess this black spot on the throat. Usually the intruder broke away and swam downstream as soon as the two fish reached the surface. In a few cases however, the intruder did not swim away and the territory-holder was seen to hit the other fish on the side, usually near the caudal peduncle, with his snout. This always frightened away the attacked fish.

Usually after a strenuous period of displaying, the victor moved to the bottom near a rock, or in many cases that I saw, at my boot, and begin a peculiar behavior. The fish turned partly over on its side and erected its dorsal fin so that it was bent over the rock or boot (Fig. 40). Then the fish quivered violently, so that the caudal fin stirred up sand and gravel on the bottom. This display lasted about 3-5 seconds and then the fish swam away - usually to the original station upstream. One particular fish performed this display 4 times in half an hour at my boot. On another occasion a fish at each boot performed these actions. This "vibrating display" as it is called by Fabricius and Gustafson was seen by them only during the spawning period.

They believe this display functionally belongs to the aggressive behavior rather than to courting or mating. They believe that the purpose of this display is to advertise the presence of the territory-holder much the same way as the song of a passerine bird or display postures of male gallinaceous birds.

What was believed to be the actual sex act was observed only once. The behavior between a male and female grayling is different from that between two males in a number of respects. The female was not seen to raise her fin in response to the male's raised dorsal fin. Furthermore, the male was seen in a number of cases following a female rather than chasing her. The sexual act which was seen was similar in many respects to the behavior described between two males but with some notable exceptions. The male and female were seen near the bottom. They were side-by-side, touching each other. The male had his fin erect and partially laid over the female, in much the same way as was seen in the vibration display on the boot or rock. The female gaped widely, but the male did not gape until just before the act was over. Fabricius and Gustafson noted this similar gaping behavior in T. thymallus. They said that the male responds to the female's gaping, which is one of the stimuli which releases the orgasm in the male. The whole act was accompanied by the vigorous vibrating motion by both sexes and the caudal fins of both fish stirred up much gravel and sand. No sexual products were seen released due to this disturbance of the bottom material. The male swam off as

soon as the act was over and the female stayed around for a few seconds, and then she also swam away. The whole act lasted perhaps 7 seconds. No redd was formed, but the eggs are covered by the loosened bottom material.

Fabricius and Gustafson say that in the European grayling the male is bent in an "S" fashion and that the caudal part of his body is crossed over the caudal part of the female, pressing it down into the bottom. This was not seen in the Arctic grayling in Providence Creek. They suggest that the huge dorsal fin acts like a "clasping organ" as it is firmly pressed against the back of the female in front of her dorsal fin and the posterior part of the male's fin covers the anterior part of the female's dorsal fin. Although the caudal region of the Providence Creek grayling could not be seen clearly, the dorsal fin was being used as described.

The bottom of the stream was sampled in a number of places to see if there was a preference for a type of bottom. It was found that pure mud, sand or clay were not chosen at all; only gravelled areas were used (Fig. 39 and 40). Ninety-six per cent of the eggs found were fertilized.

2. Food and feeding

a. Introduction

Stomach contents of 348 grayling were examined to determine what the grayling were eating and in what quantities each item of food was being utilized. All grayling were caught by angling and gill-net methods. In addition, the contents of 58 stomachs were examined from grayling

fry taken during 1964 to 1966. The fry were collected by electro-shocking and seining. The stomachs from the 1965 collection and all the fry were fixed in 10% formalin and later transferred to 50% isopropyl alcohol. The stomachs from the 1966 collection were examined in the field as soon as possible after capture. The stomach contents of the larger fish were sorted according to taxonomic groups and each group was measured volumetrically by water displacement. The stomach contents of each fry were counted. The contents were insufficient to be measured volumetrically.

b. Food of grayling fry

Table XXV is a summary of the kinds of food of the grayling fry caught in Providence Creek and Stark River. The 48 fry from Providence Creek were all about four to five weeks old. Forty-six per cent of these fish had empty stomachs. The rest of the fish had eaten mainly mayfly larvae, predominately Baetidae, and Diptera pupae, mostly Simuliidae. A few fish had eaten Cladocera of the family Chydoridae. Two fry taken from Providence Creek at a later period when the fish were about eight weeks old showed that they had fed on larvae of Baetidae, Hydropsychidae and Simuliidae. Similar results were found in Stark River when the stomach contents of eight grayling which were about 10 to 12 weeks old were examined. These fish contained mainly Trichoptera larvae (Hydropsychidae) and Diptera larvae (Chironomidae).

Kruse (1959) wrote that grayling from Wyoming in the 0 to 1 age-group subsisted mainly on <u>Daphnia</u> and on Diptera larvae and pupae.

Table XXV. Per cent frequency of occurrence of food items in age group 0.

Food Items	Providence Creek			Stark River	
	June 19, No.48 Av. length 25.1 mm	July 10, No.1 Av. length 42.5 mm	July 12, No.1 Av. length 60.7 mm	Aug. 5, No.3 Av. length 49.5 mm	Aug. 21, No.5 Av. length 56.3 mm
Empty	46	0	0	0	0
Ephemeroptera nymphs	23	100	0	0	0
Trichoptera larvae and pupae	6	0	100	0	100
Diptera larvae and pupae	21	100	100	100	100
Cladocera	6	0	0	0	0
Unidentifiable	10	0	0	66	0

Young grayling begin to take food as late as nine days after hatching (Brown, 1938a). Trout can eat large plankters on their first day of feeding (Brown, 1938a). Apparently the smaller mouth size of a young grayling prevents the taking of food organisms at an earlier time. Hartman (1958) found that although the mouth size of rainbow trout imposes a limit on the size of food swallowed, the structure and reactions of food organisms also impose limitations. Brown (1938a) also found that only nauplii of Cladocera and Copepoda were eaten from the first to the fourth and fifth weeks of feeding.

The stomachs of 22 fry included in the Providence Creek sample were empty. These were the only grayling found wit empty stomachs in the two-year study period. None of the more than 2600 larger grayling examined during the study had empty stomachs. Only two periods were seen when the stomachs of the grayling were not as full as usual. The first period was seen during the spawning run in 1966 in Providence Creek. Fish at this time were apparently not feeding actively until after they had spawned. This was noted through visual observations on the feeding behavior of the fish and also by examination of the stomach contents. Furthermore, no fish was caught by angling that had not already spawned. The other period of relative emptiness was seen briefly in the Stark River during early September, 1965, when the stomachs again contained mainly bottom fauna. This was probably due to the fact that flying insects had been eliminated by a previous week of freezing temperatures.

c. Food of larger grayling

Throughout most of the summer the grayling is a voracious feeder. In the West especially, many grayling were found with their stomachs so distended with food (mainly caddis fly adults) that the contents of the stomach could be seen through the thinly stretched stomach walls.

The grayling of Great Slave Lake will apparently eat almost anything that is available to them. Stomach contents have yielded such oddities as fish scales, feathers, pine needles, sticks, stones, and on one occasion, a part of a ham sandwich. This generality in the manner of feeding is apparently common to grayling all over the world as many workers have noted similar findings (Brown, 1938a; Rawson, 1950b; Ward, 1951; Kruse, 1959).

Table XXVI shows the wide variety of food taken by larger grayling in Great Slave Lake. There are 46 families of insects which make up the bulk of the food items and approximately 15 species of non-insect food items, among which fish and Gordiacea are the most abundant. There are important differences between the food habits of the grayling of the two main areas of the lake and within each of the areas themselves. It should be noted that the figures in Table XXVI are averages of all the fish taken under each heading and therefore provide only a general view of the food taken at each respective time period.

Roughly 71 per cent of the food found in the grayling from the West was made up of insects, whereas only about 29 per cent of the food from the East contained insects.

Table XXVI. Plant and Animal Components of Stomach Contents of 348 Grayling from Great Slave Lake (expressed as percentage of total volume).

	WEST				EAST		
Location	Mackenzie River	Mackenzie River	Kakisa River	Providence Creek	Stark River	Stark River	G.S.L. areas
Date	June 19-July 31 1965	July 6-July 29 1966	May 22-June 9 1965	May 4-May 28 1966	Aug.4-Sept.9 1965	June 1-July 5 1966	Aug.4-Sept.9 1965
Number of fish	66	47	16	39	91	71	18
Total volume (cc)	1061.0	556.7	311.8	290.4	531.3	692.3	230.9
TERRESTRIAL INSECTS							
Hemiptera							
Pentatomidae	tr	--	--	--	--	tr	.3
Lepidoptera	--	--	--	--	--	--	tr
Deptera							
Ceratopogonidae	--	--	--	.1	--	--	--
Tabanidae	--	tr	--	--	--	--	--
Syrphidae	tr	--	--	--	--	--	--
Unidentified	--	--	1.2	--	.6	tr	.8
Hymenoptera							
Ichneumonidae	--	--	--	--	tr	tr	--
Formicidae	.4	tr	1.2	.1	2.8	14.4	7.0
Bombidae	tr	.2	--	--	--	--	.1
Apidae	tr	--	--	--	--	--	--
Coleoptera							
Carabidae	tr	--	.1	--	.8	.7	3.2
Silphidae	tr	tr	--	--	--	--	--
Elateridae	.2	--	.3	--	.2	4.4	.2
Tenebrichidae	--	--	--	--	1.0	.5	1.3
Buprestidae	--	--	--	--	.3	--	tr
Cerambycidae	tr	--	--	--	tr	--	2.8
Chrysomelidae	.2	--	--	--	--	--	--
Cantheridae	.1	.1	--	--	--	--	--
Scolytidae	--	--	--	--	--	tr	.6
Salpingidae	--	--	--	--	--	tr	--
Byrrhidae	tr	--	--	--	--	--	tr
Curculionidae	--	--	--	--	.3	tr	.2
Unidentified remains	--	--	--	--	1.7	.4	.4
Total terrestrial insects	.9	.3	2.8	.2	7.7	20.4	16.9

Table XXVI. Stomach samples continued.

Location	WEST Macken-zie River	Macken-zie River	Kakisa River	Provi-dence Creek	EAST Stark River	Stark River	G.S.L. areas
AQUATIC INSECTS							
Ephemeroptera							
(nymphs)							
Ephemeridae	--	tr	1.2	tr	--	--	--
Heptagenidae	--	tr	tr	--	--	--	--
Baetidae	1.0	5.2	6.2	50.2	tr	2.6	--
(adults)							
Ephemeridae	--	.4	--	--	--	--	--
Baetidae	tr	tr	--	--	--	--	--
Odonata							
(naiads)							
Gomphidae	--	--	18.5	--	--	--	--
Aeschnidae	--	--	.2	.3	--	--	--
Libellulidae	--	--	--	2.3	--	.2	--
(adults)							
Aeschnidae	--	--	--	--	--	--	.9
Lestidae	--	--	--	--	tr	--	--
Coenagrionidae	--	--	--	tr	--	--	--
Unidentified	.1	--	--	--	--	--	--
Plecoptera							
(nymphs)							
Pteronarcidae	5.5	.6	27.7	1.8	--	--	--
Perlodidae	2.4	tr	7.3	.3	tr	tr	--
(adults)							
Perlodidae	1.7	.2	.1	--	--	--	--
Hemiptera							
Corixidae	tr	tr	.2	.9	1.2	--	.3
Notonectidae	--	tr	--	--	.2	--	--
Trichoptera							
(larvae and pupae)							
Rhyacophilidae	6.7	tr	.8	.5	tr	tr	--
Psychomiidae	--	--	.1	--	.4	--	--
Hydropsychidae	4.7	2.8	9.7	--	25.2	6.2	--
Phryganeidae	.4	tr	--	1.5	1.6	tr	--
Limnephilidae	.2	.3	--	--	.3	3.9	--
Leptoceridae cases	.3	--	--	--	.4	--	--
(adults)							
Psycomiidae	--	tr	--	--	tr	--	--
Hydropsychidae	36.0	27.4	--	--	5.8	tr	--
Phryganeidae	tr	--	--	--	--	--	--
Limnephilidae	6.0	2.6	--	--	2.0	tr	--
Leptoceridae	.5	tr	--	--	--	--	--
Brachycentridae	tr	tr	--	--	--	--	--
Diptera							
(larvae and pupae)							
Tipulidae	--	--	--	--	--	tr	--
Simuliidae	tr	--	--	--	--	--	--
Chironomidae	8.5	.5	.1	--	1.7	1.0	.5
Ceratopogonidae	--	--	--	--	--	1.0	--
(adults)							
Chironomidae	tr	tr	--	--	tr	.6	--
Coleoptera							
(larvae)							
Dytiscidae	.3	tr	1.5	.3	--	--	--
(adults)							
Dytiscidae	.1	--	.2	1.2	--	.2	1.8
Hydrophilidae	--	--	--	--	--	tr	--
Total Aquatic Insects	76.0	44.1	73.8	40.6	42.1	23.2	3.5

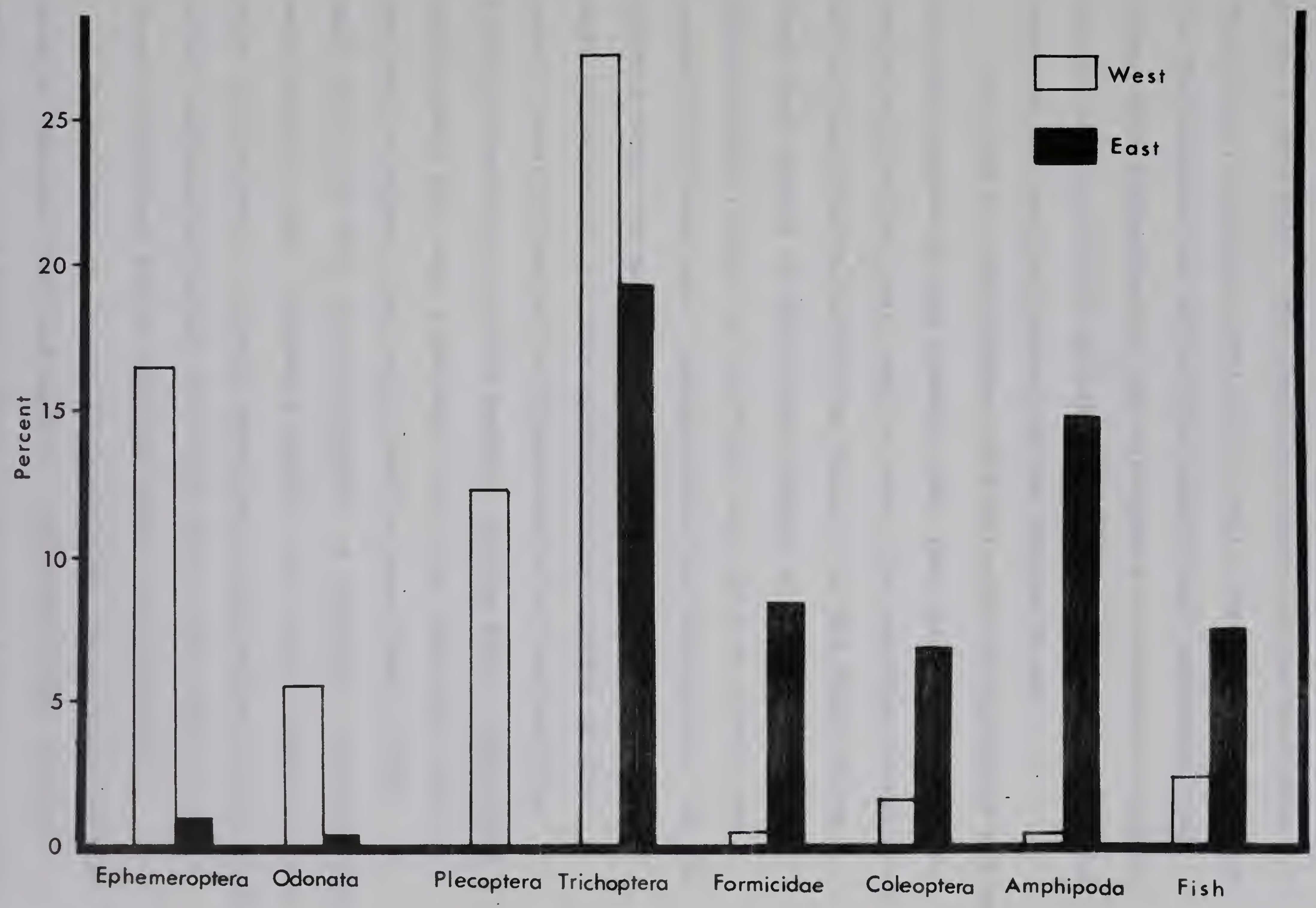
Table XXIV. Stomach samples continued.

	WEST				EAST		
	Macken-zie River	Macken-zie River	Kakisa River	Provi-dence Creek	Stark River	Stark River	G.S.L. areas
MISCELLANEOUS ORGANISMS							
Nematomorpha							
Gordiacea	.3	.3	--	--	6.9	tr	--
Bryozoa	--	--	--	--	--	tr	--
Annelida							
Oligochaeta	tr	--	--	--	--	--	--
Hirudinea	--	tr	--	--	--	.4	--
Mysidacea	--	--	--	--	tr	--	tr
Amphipoda							
Gammarus lacustris	--	--	tr	.1	--	tr	7.9
Hyalella azteca	--	--	--	1.5	--	--	--
Pontoporeia affinis	--	--	--	--	--	--	34.7
Arachnida	tr	tr	tr	--	tr	tr	--
Gastropoda	tr	--	--	--	tr	.2	--
Fish							
Cottus cognatus	--	3.6	--	--	.9	.3	--
Pungitius pungitius	--	--	--	--	1.0	.2	--
Coregonus spp.	--	--	--	--	6.0	tr	--
Unidentified	.7	.7	3.3	--	12.4	.4	--
Fish Eggs	.3	.3	1.8	10.7	--	tr	--
Vegetation	3.1	3.2	--	10.4	--	--	--
Total miscellaneous	4.4	8.1	5.1	22.7	27.2	1.5	42.6
Debris	18.7	47.4	18.1	17.6	23.0	54.9	37.0

These figures could be increased somewhat as much of the material listed under "debris" was unidentifiable insect material. It is interesting to note that of the insect material utilized by fish in the West, approximately 90 per cent is aquatic insects. In the East only 53 per cent of the insect material utilized is made up of aquatic insects. Other workers also found that insects are most prevalent as grayling food, sometimes terrestrial and at other times aquatic insects predominating (Rawson, 1950b; Ward, 1951; Kruse, 1959). Leonard (1939) found Amphipoda and Odonata nymphs as being of first importance.

Figure 41 shows the 8 most important food items expressed as the mean total percentage as taken from Table XXVI. In the East, the Coleoptera, Trichoptera, and Formicidae are the major food items. The apparent abundance of amphipods is misleading as only a few fish from lake areas were found containing them, but their stomachs were filled almost to the exclusion of any other food item. The Coleoptera and Formicidae were very common in almost all the fish caught in true lake areas in the East. Norlin (1967), in his study of terrestrial insects in the water surface of lakes in northern Sweden, found that such insects were very important as fish food because of their easy availability as prey, which compensated for their small biomass. Trichoptera and fish were very common in the diet of the grayling occupying the Stark River. Only three species of fish were ever seen in the stomach contents of grayling and these were the nine-spine stickleback, the slimy sculpin and the cisco. The

Figure 41. Eight most important food items found in the stomach contents of 348 grayling. Expressed as mean percentage of total volume.


West
East
Percent
25
20
15
10
5
0
Ephemeroptera
Odonata
Plecoptera
Trichoptera
Formicidae
Coleoptera
Amphipoda
Fish

number of fish taken as food in the West is not as great as it is in the East. The grayling caught in the West show an entirely different pattern to their feeding habits. Here the Trichoptera are by far the single most important food item, with Ephemeroptera and Plecoptera also being utilized fairly heavily in the spring. Most of the Odonata were from stomachs of grayling caught in the Kakisa River.

In general, the pattern of feeding of the grayling follows the life cycles of the insects that they prey upon. In the early part of the year, May to June, the grayling spends most of his time feeding on bottom fauna. In the Stark River, they feed mainly on larvae and nymphs of Trichoptera and Ephemeroptera, while in the West they feed on larvae and nymphs of Trichoptera, Ephemeroptera and Plecoptera. As the insects begin to emerge during July, the grayling spends more and more of its time closer to the surface of the water, usually feeding on flying adults of the emerging insects that fall into the water. In the West, caddis fly adults were the most prominent food item from late June to the end of August. Few mayfly adults were found in the East or in the West in the stomachs of grayling, although many were seen on land. Stonefly adults were fairly common in late June in the West. In both locations, grayling were seen lying under overhanging bushes and trees where they would pick up insects that had fallen off the trees into the water.

No information is available on what the grayling feeds upon in thelate fall and winter. One fish caught during March, 1966, from Moraine Point, contained almost 97 per cent

fish remains. The literature contains very little about winter feeding so this would be a profitable area of investigation.

Some food items such as Diptera larvae and adults, Corixidae and Gordius were very common in stomachs in both locations but were not found in large quantities.

Vegetation is listed separately in some cases but it is not known if it was taken as a food or accidentally. Other authors have reported vegetation in the stomachs of grayling (Rawson, 1950b; Wojcik, 1955). Many of the food items which are probably taken accidentally, such as sticks and stones, are often shaped like a true food item such as a caddis fly case or beetle.

No noticeable differences were seen between the food of small and large grayling except in size. Small grayling could apparently not eat large larvae of stoneflies and dragonflies. Ide (1942) noted that the availability of speckled trout food varies with the size of the organism relative to the size of the fish. In Great Slave Lake young grayling of the two to five age classes seemed to feed on the same foods as the older grayling.

There was no apparent distinct feeding time during the daylight hours. Grayling were seen to feed at all times of the day and were caught by angling at all times of the day. There was little fishing done at night but it was found that in the few hours of real darkness in the summer, the grayling does not bite as well as during the day time. Reed (1964) stated that grayling in Alaska stopped feeding

during the night. There was some indication that grayling do not feed well during a heavy rainstorm or during heavy winds when the water is greatly disturbed. Fish caught after such storms usually contained stomach contents that were well digested, indicating that little fresh food had been taken recently. The fish stopped biting completely in the Kakisa River after heavy rainstorms which muddied the water. Shallock [n.d.] also noted the difficulty in capturing grayling when the water was turbid. Grayling do appear to feed during light showers of rain or mild summer storms. They can be taken by angling during such disburbances.

3. General behavior and distribution of grayling and other species of fish in the West.

a. Grayling

By far the greatest concentration of grayling was found in the vicinity of Brabant and Lobstick Islands (Stations 1-3, Fig. 2). This area was characterized by being close to deep channels of water and having islands whose trees hung over the water. The bottom in this region is generally quite free of vegetation and is composed of large stones, three to four inches in diameter. The shore line drops off at about a 100 to 200% grade. The water flow is fairly swift past the islands.

Station 4 contained grayling only at certain periods during the summer. This location was quite shallow in places, about two feet, and the bottom was weedy. Station 6 only yielded a few grayling, but I did talk to some tourists

who professed good luck in this vicinity.

Station 10 also yielded only a few fish and the presence of grayling in this area in particular, and probably all along the south shore, is believed to be dependent upon the water temperature. As can be seen from the temperatures in Figure 2 and Table XXVII, the water temperature increases considerably as the river is crossed from North to South. On July 2, 1965, the temperature at Station 1 was 7.5 C, whereas at Station 10 it was 14.5 C. Similarly, on July 13, 1965, the temperature was 11.5 C at the North side of the river and 18.9 C at Station 10. Grayling were taken in the vicinity of Station 10 only on two occasions and both times the temperature here was similar to that on the North side. It is believed that this warm water is caused by the turbid Hay River which flows into Great Slave Lake about 30 miles East. It is reported that on occasion from the air, the yellow, muddy water of the Hay River can still be seen quite distinctly, flowing along the southern shore of Great Slave Lake down to the Mackenzie River. As the water of the Hay River is much warmer than that of Great Slave Lake, it is not surprising that it could still be distinguished when at the Mackenzie River. This general pattern of warmer water on the South shore of the Mackenzie River is common throughout the summer but it is periodically disrupted after a storm or strong wind. After such a storm the temperatures on both sides of the river is generally equalized.

As was mentioned earlier in the section on Sex Ratio (p. 44) the male to female ratio in the West is heavily in

Table XXVII. Mackenzie River water temperatures.

Date	Northern part of river - Brabant I.	Southern shore of river	
June 26, 1965	3.5 C	12.5 C	(June 25)
June 20, 1965	8	15	(June 28)
July 2, 1965	8	15	
July 13, 1965	12	18	
July 26, 1965	14	15	
July 15, 1966	15.5	20.5	
July 28, 1966	13.5	14	

favor of the males according to the catch statistics (1.84:1). The predominance of males exists in both the mature and immature groups. No definite explanation can be given for the phenomenon, although the behavior of the grayling may hold the answer. It is my belief that only very large female grayling hold territories. As was seen in the Growth results (Fig. 22, p. 57), many more large females were caught in the Mackenzie River area than small ones. It may be then that the Brabant Island region is simply being occupied by those fish big enough to hold a territory. Thus a very large female could conceivably occupy a territory against a smaller, although perhaps a more aggressive, male. It may be that the majority of the smaller but mature females would be found in the same locations as the younger, sub-adult males.

Fabricius and Gustafson (1955), wrote that grayling aggressiveness is common to both sexes and at all times of the year and occurs in immature specimens as well as adults. They note that outside of the breeding season the grayling in streams tend to form schools, and within such schools each fish maintains its own station, usually over a stone or a tree root on the bottom.

The grayling that could be seen around the islands in the Mackenzie River did not form schools but were dispersed in a regular manner fairly close to the shores of the island. They seemed to prefer hiding under overhanging trees and darting out to pick up fallen insects that dropped from the trees. Each overhanging tree usually had a grayling under it. It is believed that this territorial behavior would help

disperse the grayling in this area.

b. Other species of fish

Besides the Arctic grayling, the Western area has a number of other abundant fish. Of the game fish, the pike is by far the next most abundant, after the grayling, in this region. Pike occur almost everywhere in the region but prefer the warmer, shallower water and so are especially common along the south shore. Known areas of abundance are Stations 6, 7, 10 and 12.

The yellow walleye is found only in the warmer water zone of the south shore, although not in great numbers. They were caught in nets and by angling at Station 10.

The other game fish of this area is the lake trout. Most of the lake trout were caught in nets at one location at the south-west end of Brabant Island in Station 1. This particular location has a deep hole, about 10 feet deep, located close to the shore. The trout occupied this area only for about one week in July when the water temperature rose from 8 C to 14 C. The largest trout taken in gill nets weighed 41.7 pounds. This was the largest trout caught during the two year study of the lake.

Of the non-game fish, the lake whitefish is the most abundant in this area and is found in most of the open areas close to deeper water. Both longnose , Catostomus catostomus (Forster) and white suckers, Catostomus commersonii (Lacépède) spawned in this area around the end of June in the shallow areas of Station 4. At that time the water temperature was around 5 C. Burbot, Lota lota (L.), were found only in

two locations, Stations 1 and 2. Ciscoes, Coregonus spp., were found only incidentally, although many were believed to be seen rising in front of our campsite in the Station 2 area. At these times they could be caught by fly fishing.

Lady Evelyn Falls on the Kakisa River is a favorite angling spot. In the spring (May to June), there are four species of fish spawning at the base of the falls - grayling, pike, yellow walleye and longnose suckers. The grayling are reported not to stay in the river much past the end of June.

4. General behavior and distribution of grayling and other species of fish in the East.

a. Grayling

Figure 5 shows collection sites for grayling in the East end of Great Slave Lake. By far the most time was spent at Station 1 in the Stark River. It was from here that about 62 per cent of the grayling were collected.

Temperatures for Stark River and Stark Lake are shown in Table XXVIII. Few grayling were caught in the early spring (from about June 1 to June 16) when the water temperature was about 4 C in the Stark River. Both the main lake and Stark Lake were covered with ice at this time of the year but the river was free of ice. During this early period very few grayling were caught in gill nets. Grayling could be seen lying near the bottom but they did not seem to be interested in hooks or flies. The water warmed up considerably by the middle of June to about 8 C. It was about this time that grayling started to take flies and angling became more profitable. They were being taken at

Table XXVIII. Stark River area water temperatures.

Date	Stark River (mouth)	Stark Lake
June 3, 1966	2 C	2 C
June 10, 1966	4	2
June 17, 1966	7	5
June 26, 1966	8	8.5
July 1, 1966	6	11
July 4, 1966	-	15
August 4, 1965	16	-
August 7, 1965	-	15
August 20, 1965	12	13
August 29, 1965	9	-
Sept. 4, 1965	9	-
Sept. 9, 1965	9	-

about 5 per rod hour. Most of the grayling caught in the early summer of 1966 were caught either at the source of Stark River or at its mouth. After July 1, there were very few grayling to be seen or caught near the mouth of the river, probably due to the large numbers of lake trout which had moved up into the bay near the mouth of the river (see following section). In August, 1965, more grayling were caught by angling in the middle of the river, usually in the general area of the First and Second rapids.

The grayling caught in the river itself were generally smaller than grayling caught in the lake areas of the East. Reasons for this are discussed in the section on Growth (p. 54). The ratio of males to females in the East was approximately 1:1.

Station 2 in the East included all the shore-line of Stark Lake around the source of Stark River. Most of the grayling were caught in the shallow northern shoal area in about two to ten feet of water. Nets were set in deeper parts of Stark Lake nearby but no grayling were ever caught.

Station 3 is on Snowdrift River which is another clear, fast-flowing river located five miles south of the Stark River (Fig. 8). This river can be navigated for about 3 1/2 miles upstream, where progress by boat is stopped by falls which are about 8 feet in height. Grayling were caught on both sides of these falls so they can probably ascend the falls. The numbers of grayling did not seem to be very plentiful the few times this Station was fished, but I have talked to tourists who have had good luck in the river, especially at

its mouth at Stark Lake. The Snowdrift River looks like ideal spawning territory for the grayling although no young grayling were caught by seining. It is impossible to get to the river in early spring except perhaps by overland trek, as Stark Lake is frozen over until about the middle of June.

Stations 4 to 9 were all areas that were investigated through the use of gill nets. All areas investigated contained grayling. At all stations grayling were caught in shallow water in nets set at two to twenty feet in depth. By far the majority of grayling were caught in water 12 feet or less in depth. Rawson (1951), captured no grayling in Great Slave Lake below 20 to 30 feet of water. Depths in the regions of Stations 4 to 9 were very deep. Depths near Station 5 were about 400 feet.

Station 7 ("Gray Bay") yielded the best results for gill netting in the entire lake; 111 grayling were caught in 17 nets that were set overnight. The fish from this area were small, about one pound, in comparison to other grayling taken from the other lake stations, which averaged about 1 3/4 pounds. Scales from the fish caught at Station 7 were very difficult to age and for that reason they have been omitted from any age, length or weight data. Many of the fish showed only two or three annuli yet were the size of four and five year old fish. No explanation can be given for this but there is some evidence that annuli may have been reabsorbed. It would seem that this Station would warrant further investigation.

b. Other species of fish in the East

The most important sports fish in the eastern end of the lake is the lake trout which is found in great numbers at certain times of the year, especially near the mouth of the Stark River. As mentioned previously, the grayling were seen to be displaced at the mouth of the Stark River by trout moving into the same area near the beginning of July. The trout were generally found in the faster water that flowed from the river into the lake at which point the depth was approximately 20 feet. Water temperatures at the time of this displacement were about 8 to 9 C. At dusk, the trout would rise in great numbers to the surface of the water, presumably taking fallen insects from the surface. They could be caught on artificial flies during this period and would take small and large spoons. Generally it seemed that it was the smaller fish that were rising (i.e. fish about two pounds) and the larger fish could only be caught by trolling or casting large spoons. Our best record for catching lake trout was during this period, when about 10 fish per rod hour were caught, which had an average weight of 3.5 pounds. One party of four men reported that they caught an estimated 200 trout in about four hours from this location at the mouth of the Stark River. During July lake trout were caught occasionally by anglers who were fishing for grayling in the Stark River itself. The lake trout do not appear to stay near the mouth of the Stark River all summer long but seem to disappear during the month of August. The water temperature in August averages around 12 C in the Stark River. Throughout

most of the summer, anglers try to catch the larger lake trout by trolling deep in the more open parts of the lake, especially in Stark Lake and around Pearson Point (Station 5) in Great Slave Lake.

Lake trout were caught in nets at all Stations in the East except 1 and 3 which did not have any nets set at all. As our nets were set to catch grayling, all sets were in shallow water. Even so trout were taken in good numbers, sometimes in as little as two feet of water. This may indicate that lake trout come into the shallower water at night to feed. It was noted that lake trout from Great Slave Lake were silvery in color whereas the trout caught in Stark Lake were dark brown. The largest lake trout caught in the East weighed 30 pounds.

The next most important sports fish found in the East is the northern pike. Although the pike is not as numerous as it is in the West end of the lake, there are certain locations where it can be found in fairly large numbers. Stark Lake is probably the best location in the Snowdrift area to catch pike by angling. They were caught in good numbers along the southern shore of the Stark Lake close to the mouth of the Stark River and also in the vicinity of Station 4 at the eastern end of Stark Lake. The largest pike caught in the two summers on the lake weighed 26 pounds and was caught at Station 4. The pike prefer the shallower and more protected waters, 2 to 20 feet in depth. Pike were also caught by angling in the Snowdrift River at the base of the falls.

Whitefish were very plentiful in all areas where gill nets were set (Stations 2, 4 to 9). Generally the larger fish were caught in deeper water, at depths greater than 15 feet. One whitefish was caught by angling in the Snowdrift River. Its weight was four pounds.

The menominee (Prosopium cylindraceum (Richardson)), was especially numerous in Stations 5 and 6 and was common in all other areas where gill nets were set.

The longnose sucker is common in these waters in the East, especially in the early spring when they are supposedly migrating to and from their spawning grounds. They were very plentiful near Station 2 and at times near the mouth of the Stark River in the shallow, quiet water. Only one white sucker was caught in the East and it was caught in Stark Lake.

Revlatively few ciscoes were caught but this may be because their small size allowed them to pass through the larger mesh of our nets. Ciscoes were found in the stomachs of lake trout, pike, burbot and grayling.

The majority of the burbot were caught in nets set in the open waters of Great Slave Lake, especially at Stations 5, 7 and 8.

5. Competition and predation

All the fish caught with the grayling were examined from the point of view of determining which were competing directly or indirectly with the grayling. Many of the data were obtained from observations in the field so not much could be proven experimentally. Competition here will be

dealt with from three main aspects: competition for spawning grounds, competition for space, and competition for food.

a. Competition

Three fish may be competitors with grayling for spawning space in the spring. These are northern pike, yellow walleye, and longnose suckers. Pike were observed spawning in Providence Creek at the same time as grayling were spawning. As no pike were seen in the act of spawning, it is not known if they utilized the same type of bottom as the grayling, but it can be assumed that owing to the small size of the creek, the two species would be in direct competition some of the time. In the Kakisa River there were pike, walleye and longnose suckers spawning about the same time as grayling. As the river was too deep and wide to observe any spawning activity it was impossible to tell how much the four species competed for spawning grounds.

From Figure 11 it can be seen that the grayling are caught with, and presumably live close to, a large number of species of fish. In the discussion of competition for space the other species of fish will be considered as potential competitors if they are found in large numbers with the grayling, because ecological information on most other species of fish in Great Slave Lake is incomplete. The pike, trout and burbot will be considered as predators and will be dealt with shortly, although their presence could probably be considered as competition for space.

The three main species of fish that appear to be most important as competitors for space are the common whitefish, the longnose sucker, and the menominee.

The menominee can only be considered important in the eastern part of the lake for very few were caught in the West (Fig. 11). In the East, the menominee are found in the same general area as the grayling only in Great Slave and Stark Lakes. They were never seen in the Stark River, although presumably they do traverse the river for they were caught in the headwaters and at the mouth of the river. Of the 633 menominee caught during 1965 and 1966, 598 (94.4%) were taken from either Great Slave Lake proper or in Stark Lake. None were ever caught by angling. Only 38.1% of the grayling from the East were caught in the lake areas proper. From this it can be assumed that if the grayling competes with the menominee for space it does so only the lake areas in the East part of Great Slave Lake.

The common whitefish was caught in large numbers with the grayling in both the East and West locations. It also may be considered as a competitor for space only in the main lake areas of Great Slave Lake. The same holds true for the longnose sucker which was always present in lake areas or in slower moving water. Longnose suckers probably traverse the Stark River, expecially during its spawning time in the spring.

Rawson (1951) found that the grayling, white sucker and walleye are largely inshore species. He considered the menominee to occupy an intermediate position to the inshore

species and the offshore longnose suckers. As white suckers and walleyes were caught very infrequently and in few numbers I do not consider them important competitors for space.

There is some indication that the grayling of the 0 and 1 year age group compete with the young of the above-mentioned fish and other as they were always caught together with these species, especially the pike and longnose sucker.

The grayling has few real direct competitors for food although a few species overlap in the food choices. It was found from general observations that the menominee and common whitefish feed mainly on gastropods but often contain the larvae of mayfly and caddisfly in their stomachs, although the latter were never in large quantities. In the study of Pontoporeia and Mysis in Great Slave Lake, Larkin (1948), concluded that Pontoporeia provided the common white-fish with 60% of its food. The remainder of the white-fish's food was sphaeriids, gastropods, chironomid larvae and miscellaneous organisms in decreasing order of importance.

Rawson (1951) found that caddis fly larvae and pupae were found in 82% of the stomachs of menominee and they averaged 43% of the total volume of the stomach contents. Gastropods were found in 51% of the stomachs and contributed 35% of the material. The remaining 21% of the stomachs contained the larvae of aquatic Diptera, mostly chironomids and tabanids which made up an average quantity of 21%. It appears then, that the menominee is probably more of a competitor than the common whitefish when competing with the grayling for food.

Grayling fry and fish of the year, may be in direct competition with the slimy sculpin (Cottus cognatus Richardson) and the nine-spine stickleback (Pungitius pungitius Linnaeus) for food as both of these smaller fish were found to contain similar bottom organisms as the grayling, namely mayfly larvae, and caddis fly larvae and pupae.

Schallock [n.d.] reported that Cottus cognatus, Prosopium cylindraceum and Catostomus catostomus were the principal competitors for food with the Arctic grayling in the Chatanika River in Alaska.

Observations on the stomachs of the suckers taken from Great Slave Lake were almost valueless as it was impossible to detect what they were eating. Rawson (1951) also noted this difficulty, but judged that the average per cent of foods taken was amphipods 63, chironomid larvae 15, other aquatic insects (mostly caddis) 11, and sphaeriids 9. Thus, it would appear that the longnose sucker is competing directly with the grayling during part of the year. It must be noted that although all the aforementioned species do eat the same food as the grayling and are found in the same areas as the grayling, the grayling does change its food habits during the year when the insects upon which it feeds begin to emerge (see section on Food and Feeding, p. 115). The menominee, common whitefish and longnose suckers are all principally bottom feeders so they would no longer be in competition with the grayling when the grayling is feeding at the surface of the water.

During July grayling were seen to move out of certain parts of the Stark River, especially at its mouth, apparently because lake trout had moved into these areas. The trout were observed rising to the surface presumably taking fallen insects for food. They would also taken an artificial fly during this period. Besides being a predator to the grayling, the trout was also competing with it for food and space.

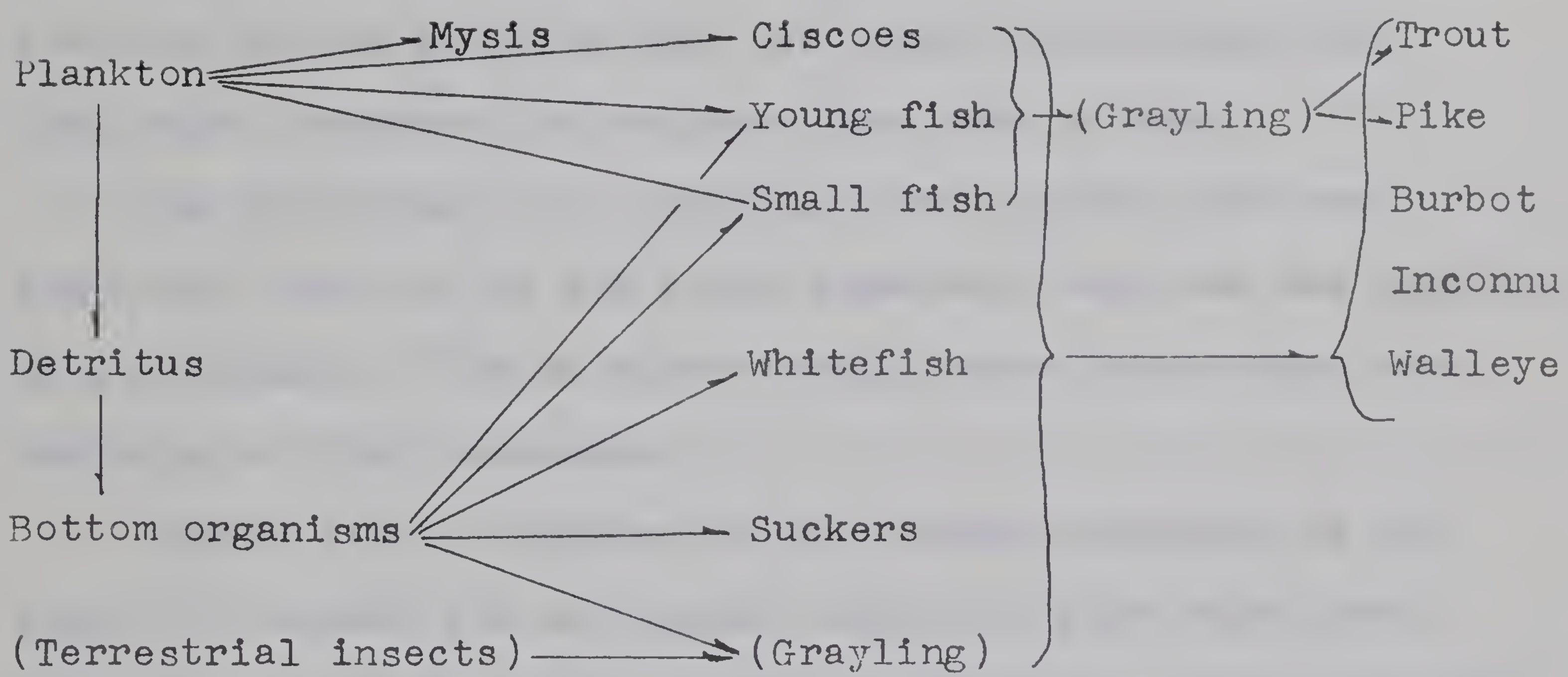
Rawson (1951) designed a chart to show the principal food chains among the fishes of Great Slave Lake (Fig. 42). To this I have added the grayling according to my results. Because of the grayling's wide variety of food, which changes at times throughout the year, the grayling can be classed as a secondary consumer when feeding on bottom and terrestrial insects and a tertiary consumer when it feeds on ciscoes and small fish.

b. Predation

The Arctic grayling in both main locations in the Great Slave Lake lives in close association with potential predators such as the pike, lake trout and burbot. Rarely were grayling found in the stomachs of any of these fish.

A total of 820 pike, all of which were heavier than 1 pound, were checked for stomach contents. Of these only eight had identifiable grayling remains in their stomachs (.9%). As mentioned in the spawning section, pike were seen in Providence Creek during their spawning season so a check was made in July, about one month after the spawning

Figure 42. Principal food chains among fish of Great Slave Lake (modified after Rawson, 1951, parentheses indicate additions).


Plankton
Mysis
Ciscoes
Young fish
Small fish
(Grayling)
Trout
Pike
Burbot
Inconnu
Walleye
Detritus
Whitefish
Bottom organisms
Suckers
(Terrestrial insects)
(Grayling)

period, to see what the fry were eating. As pike are known to be very voracious when they are young it might be supposed that they would be feeding on small grayling. The pike at this time were about six cm in length. Thirty-seven of the small pike were examined for stomach contents and six of these had fish in their stomachs, four of which were pike, and the other two unidentifiable.

Another potential predator seen in Providence Creek at this same time was the dytiscid larva, which was three times the size of the grayling fry, and could conceivably prey upon them. However, no evidence was seen of this.

The only other predator found in the lake was the trout, yet out of 578 trout examined, only one had grayling in its stomach. The 46 burbot caught were never found with grayling in their stomachs.

Rawson (1951) reported on the stomach contents of 650 trout, 87 burbot and an unnamed number of pike from Great Slave Lake. Of the 486 trout that had food in their stomachs, fish contributed to 90% of the food items. More than half of the identifiable fish were ciscoes. Other fish found were cottids, burbot, common whitefish and longnose suckers. Fish made up 75% of the food of the burbot, with ciscoes, cottids, whitefish, sticklebacks and trout perch being the most important in that order. The food of the adult pike was found to be 95% fish. The fish eaten by the pike, in order of abundance, were ciscoes, cottids, sticklebacks, burbot, common whitefish, round whitefish, pike perch, and gold-eyes. No grayling were reported in any of Rawson's findings.

A few pike which had been eating lamprey ammocetes (Lampetra japonica (Martens)) were caught in the headwaters of the Mackenzie River in 1965.

From the above findings, it appears that the grayling has quite successfully managed to live in close association with predators, yet somehow kept from being eaten. A clue as to the means by which this is achieved may be found from the following observation, from the Mackenzie River section where the grayling were seen to be holding territories. A large male grayling (verified by capture) was seen close to the shore, apparently in his territory. A pike, which was slightly larger than the grayling, swam into the territory from downstream. The grayling immediately erected his dorsal fin, and waited in one spot. The pike manoeuvered to within 6 inches of the grayling and then the grayling appeared to let himself be carried downstream by the current as he still faced upstream. The pike made no move to pursue the grayling which still had its dorsal fin erect. The whole encounter lasted about 20 seconds, and as soon as the pike moved on upstream, the grayling returned to its original position, its dorsal fin now flattened. This observation, coupled with the fact that a number of grayling had dorsal fins that showed bite marks, suggests that the fin may serve two purposes in helping the grayling evade a predator. The first purpose is that the erect dorsal fin would increase the fishes' outline size by approximately 1/5, making him appear much larger than he actually is. The second purpose may be that if the predator does attack the grayling,

it stands a good chance of biting into the fragile dorsal fin rather than the body of the grayling, thus giving the grayling a chance to escape.

In conclusion, I do not believe that the grayling of Great Slave Lake has any serious competitors or predators. Support for this statement lies in the fact that grayling are found in very large numbers in the lake at present times. It is believed by some that the secret of the grayling's success lies in the fact that they occupy waters that have no competitors (Brown, 1943). In general, whenever exotic trouts, such as rainbow, brook or brown trout, have been introduced, grayling numbers have tended to decline (Vincent, 1962). If, in the future, a proposal is made to introduce exotic species of fish into stream occupied by grayling, the consequences of such a move should be well considered before any action is taken.

VII. CONSERVATION AND MANAGEMENT

1. Angling information

The Arctic grayling of Great Slave Lake is not a difficult fish to catch by angling. This is mainly because it has a varied diet and apparently feeds throughout most of the daylight hours.

Angling success depends largely on three things: what time of the year it is, the type of gear used and the location being fished. In the Mackenzie River location small lures or spinners (such as Len Thompson #6 and small Mepps spinners) are best in the early spring. As the insect bottom fauna begins to emerge and the fish begin feeding closer to the surface, fly-fishing becomes the more efficient method of angling. In was found, however, that the Mepps spinner with horsehair-covered treble hook was fairly successful all summer long. As the grayling in the Brabant Island region of the Mackenzie River are found dispersed along the islands, in territories, the best success for angling was had by drifting with the current in a boat, about 20 to 30 feet out from the shore. This allows one to pass through a number of territories and gives one a better chance of catching more fish. By fishing from one spot, either in a boat or from shore, one is limited to the number of grayling in the area within ones reach. A favorite haunt of the grayling is under overhanging trees and shrubs, where the fish lies in wait for falling insects.

In the Stark River, the method of capture is much the same. Small spinners are best early in the year immediately after ice break-up, but here fly fishing is by far the best method throughout most of the summer, including most of the spring. Probably this is because there are many floating insects coming down from Stark Lake. Although grayling are caught almost anywhere in the Stark River, they seem to be most plentiful in the regions of the First and Second Rapids. It is best to anchor in a place near or in the rapids. Allowing the current to carry you downstream is dangerous because of protruding rocks and the swiftness of the river.

The type of fly used apparently does not matter, although everyone has his favorite; some of the most used flies are: Royal Coachman, Mosquito, Black Gnat, Ginger Quill, Brown Hackle, Red Ibis. A No. 12 hook is the best all-around size to use, but fish can be caught with as small a hook as #16.

The grayling rarely swallows a lure. It is most often caught by the hook in the fleshy parts on the rim of the mouth. Even so, very few fish manage to dislodge the hook once it has been caught. Once they are in the boat, the hook is usually easily removed from the grayling's mouth.

2. Angling statistics

Table XXIX shows the results of angling in the summers of 1965 and 1966 in the Mackenzie River area and the Stark River area. These results show that there are less fish

Table XXIX. Results of experimental angling at both main locations in 1965 and 1966.

Location	Number of fishermen	Hours fishing	Number of grayling	Per-rod-hour
Brabant Island 1965 (June 19-July 31)	2	194	272	1.4
Brabant Island 1966 (July 6-July 29)	2	55	273	4.9
Stark River 1965 (Aug. 3-Sept. 11)	4	117	657	5.6
Stark River 1966 (June 1-July 5)	2	65	160	2.5

caught per unit of effort in the early part of the year (June and July), than in August and September. This is true of both locations and is probably because the grayling are still moving in from their spawning areas. The low unit effort obtained at Brabant Island in 1965 is due to a number of reasons. The hours fished include many hours spent in areas with few or no fish as it was necessary to sample all areas. Secondly, we were inexperienced in the best ways of angling for grayling. Table XXX shows the results of the angling effort between the stations in the Mackenzie River. Station 1 (Fig. 2), located on the southern shore of Brabant Island produced the best catches of grayling per-rod-hour in both years of the study. Station 2, located on the northern and eastern shores of Brabant Island, was next highest in both years. These two stations, along with Station 3, are located close to the deepest channel of the river and receive a strong, cool current of water, making Brabant and Lobstick Islands with their overhanging, bush-lined shores, ideal grayling territory. Stations 4 and 10 have already been described in the section on General Behavior and they only have grayling at certain favorable periods when the water is clear and cool.

By the time we reached the Stark River in August, 1965, we were more experienced grayling fishermen. The Stark River was also small enough to find the good locations of grayling very quickly so little time was wasted fishing unproductive spots. These two factors combined to give the high number of fish per-rod-hour (5.6) (Table XXIX). The

Table XXX. Results of experimental angling at Brabant Island stations, 1965 and 1966.

	1965			1966		
Station	Hours	Number of grayling	Per-rod-hour	Hours	Number of grayling	Per-rod-hour
1	17	43	2.5	24	189	8.0
2	64	89	1.3	12	50	4.2
3	78	92	1.2	11	24	2.2
4	37	47	1.3	6	9	1.5
10	1	0	0	2.5	1	.4

low figure obtained in the Stark River in 1966 is probably due solely to the fact that there were few grayling present for much of the month of June, for reasons already given (see p. 122).

Table XXXI shows the results of the Creel Census conducted at the two locations for both summers. The low figure for unit-effort in the Brabant Island region is likely because much time was wasted by the fishermen looking for the best fishing spots. Also the weather at this time was very poor. Few tourists came to this area equipped for fly fishing, but those who did, had much better success than those who used casting methods. Fishermen coming to the Snowdrift region were generally better equipped, stayed longer and had native guides, all of which helped them to catch more fish per unit effort.

The numbers of grayling caught per-rod-hour as shown in Tables XXIX and XXXI compare favorably with the figures obtained by Keleher (1962), in his preliminary survey of the sports fishing of Great Slave Lake. He also found that fly fishing was better than casting or spin-casting with spoons. The over-all figures obtained from the angling statistics indicate that the grayling are very abundant (see Fig. 43).

In Minnesota, 300,000 grayling fry were introduced in 1955 into Twin Lake, which has a surface area of 40.3 acres. A creel census was conducted on the first grayling season in 1957, and the catch per-rod-hour was only .29 (Micklus, 1961). In Alaska figures from creel census data indicate that the

Table XXXI. Results of creel census at both main locations for 1965 and 1966.

Location	Number of anglers	Hours of fishing	Number of grayling	Per-rod-hour
Brabant Island 1965 (July 5-July 31)	11	391	382	.9
Stark River 1965 (Aug. 3-Sept. 11)	22	105	283	2.7
Stark River 1966 (June 23-July 1)	16	57	169	2.9

Figure 43. Two and one-half hours of fly-fishing by two anglers - 63 grayling. Stark River, September 1965.

rivers yield a fairly high number of fish per unit effort but not quite as high as the less exploited Great Slave Lake populations. The Clearwater River showed a unit effort of .31 fish per-rod-hour and the Chatanika River showed 1.22 (Reed, 1961). The Salcha River had a unit effort of .64 fish per-rod-hour (Heckart, 1964).

3. Angling pressure

Until 1965 at the Mackenzie River area there were no tourist facilities other than those provided by the tourists themselves. Fishermen usually tented on Brabant Island and somethings on Lobstick Island. Usually tourists were flown in from Hay River, 32 air miles away, or travelled up the Mackenzie River from the ferry crossing on the Yellowknife Highway, 40 miles downstream. In 1966 Brabant Island Tourist Camp was begun under the ownership of Mr. W. R. Hupp and Mr. R. B. Chalmers of Hay River, N.W.T. Brabant Island Tourist Camp has six cabins which sleep four to six people each. In 1966 there was an estimated 45 to 50 people at the camp (Hupp, pers. comm.). Anglers came to this area mainly to catch grayling and pike, although walleye and sometimes lake trout are also caught here.

In the vicinity of Snowdrift there are two fishing lodges. Snowdrift Fishing Lodge, located about 1/2 mile north of the Stark River was closed in 1965 and 1966, but is reported to be under new ownership and will probably be operating in the near future. Frontier Fishing Tours' camp is located near the mouth of the Stark River. This

lodge is run by Mr. J. Bricker of Edmonton, Alberta. The lodge can accommodate about 20 people for which it supplies boats, guides and board. They had approximately 100 guests in each of 1965 and 1966 (Bricker, pers. comm.). Anglers came to this region mainly for the lake trout fishing, but there are also good numbers of grayling in Stark River and northern pike in Stark Lake.

As Table XXXI indicates, the fishing pressure on the grayling is not very heavy yet, in either location. This will undoubtedly change as more facilities are made available. It is also suspected that the popularity of grayling fishing will grow as more and more people start to move into the northern regions to live and to visit. The grayling is already considered an endangered species in the greater part of the U.S.A. (Stroud, 1964), and is rare in most of Canada, making the grayling an attractive trophy for those fishing the plentiful populations of grayling in Great Slave Lake. Besides this, the grayling puts up a good fight when angled with light tackle and it is good to eat.

As the grayling has become depleted or even extinct in certain parts of North America, some steps should be taken to preserve the grayling in Great Slave Lake before their numbers decline here also. The present rules allow a person to kill not more than 10 grayling in a day. More than this number can be captured and released. This is in fact what happens to most of the grayling that are caught. In both locations during this study, the majority of the grayling that were caught by tourists, were released. A few were

eaten and some of the larger ones were taken out as trophies. There is some question about the practicality of releasing grayling after catching them for some grayling that had put up a hard fight were seen to turn belly-up when released. Andrews (1961) reported that unsubstantiated reports from anglers and camp operators in Alaska, indicated that the hooking and releasing mortality is appreciable in sports fish caught in the region.

4. Recommendations for management

1. At present there does not seem to be a need for a size limit, although this may have to be invoked if the average size of the grayling caught in the future starts diminishing rapidly. A size limit of about 14 inches would be the best size as about 80 per cent or more of the grayling are mature by this size in both locations. Such a size limit would, however, mean that many of the fish caught in the Stark River would have to be thrown back as the average size of the grayling caught by angling during this study was about 13 inches. The Mackenzie River area would not be badly affected by such a regulation as the average size of grayling caught by angling was about 15 inches. It is recommended that a follow-up study be carried out in about three to five years time to determine if any changes in average size have taken place. A close watch should particularly be kept on the Stark River. If it is proved, as is suspected, that this river is the location of young fish which will, upon reaching maturity, repopulate the lake

areas, then damage or over-fishing in the Stark River may have far-reaching consequences to the whole area.

2. No restrictions are necessary for the commercial fisheries in its present state in Great Slave Lake as most grayling occur in closed areas and/or shallow water. Records show that the effect of commercial fishing is negligible on grayling populations (Keleher, pers. comm.).

3. A study of migration should be undertaken soon to determine how and where grayling move throughout the year. Plastic subcutaneous tags have been used with good success in Alaska (Schallock, 1965).

4. It is felt that there is not need for any period of closure during the spawning season, at least in the Kakisa River and Providence Creek, as the grayling do not appear to feed until after they have finished spawning. As there are reports of grayling being taken during their spawning time by illegal methods such as seining, netting, snaring, spearing, etc., the spawning sites of grayling should be watched closely to prevent interference with spawning.

5. Although difficult, a winter study of the grayling would be extremely helpful in filling in the gaps in the life history of the grayling in Great Slave Lake.

6. As grayling do not take a hook very hard, no need is seen yet for restricting the angling for grayling to single and/or barbless hooks.

7. It is recommended that the lodge owners be asked to keep records of the fish caught at their lodges at least the numbers and species of fish caught and the hours fished.

It would be useful for fish-record books to be designed and made available to all camps.

8. As pointed out earlier, the grayling has no serious competitors. However, any introduction of exotic species may have serious consequences on the survival of the grayling. As long as habitat conditions remain the same and no exotic fishes are introduced, the grayling of Great Slave Lake will probably continue to exist in large numbers with a minimum of management.

VIII. SUMMARY

1. Grayling were caught in Great Slave Lake by angling, gill nets, seining and electro-shocking. Grayling were studied from two main areas in the lake, the Mackenzie River area in the West and the Stark River in the East. Each grayling had the following data taken from it: fork length, weight, girth, sex, and sex condition, and a scale sample. 2628 grayling were used in the study.

2. Growth curve results showed that male grayling were only slightly larger than females in both main areas. The grayling from the West were larger than the eastern grayling by about 2.5 cm in age-groups 2 to 12. The western grayling are presumed to gain the advantage in length and weight sometime during the 0 to 1 age group. The condition factor k showed that western fish are plumper than eastern grayling in all age groups.

3. In the East the male to female ratio was approximately 1 to 1, whereas in the West, the male to female ratio was 1.8 to 1 in favor of the males. The behavior of the grayling is offered as a possible reason for the disproportionate ratio in the West. It is thought that female grayling are located away from the mature male grayling.

4. Ninety-five per cent of the grayling from the West are mature at the age 6 and not until age 7 are 95% of the eastern grayling mature. Descriptions of the gonads of immature,mature and "questionable" grayling are included.

5. The spawning of the grayling was studied in May, 1966, at Providence Creek. There were 1.3 to 1 males to females in the spawning run. Eggs were artificially fertilized and raised to hatching. Time from impregnation to hatching was 13.7 days at an average water temperature of 9.1 C. The number of eggs/female was estimated by volumetric displacement. Results showed that there were an average of 310.9 eggs per ounce of female grayling. Careful observations on the spawning and feeding behavior of the spawning grayling were made.

6. The food of the grayling, as shown by examination of stomach contents, showed that the Western grayling is largely dependent upon aquatic insects as food, the most important insect being the Trichoptera. In the East the grayling feed mainly on equal proportions of aquatic insects, terrestrial insects, and miscellaneous organisms such as fish and amphipods. The feeding habits of the grayling show them to be very versatile, with a large range of food being eaten.

7. The general behavior of the grayling and other species of fish is described briefly in each of the main locations.

8. A list of parasites found in the grayling is given.

9. A survey of fish caught with the grayling showed that there are probably few close competitors with the grayling. Pike and lake trout were found to be the only

predators of grayling but the predation rate was very low.

10. Methods of angling for grayling are described for different conditions and times of the year. Experimental angling showed that 817 grayling were caught from Stark River at an effort of 4.5 fish per rod-hour. In the Mackenzie River, 545 grayling were caught experimentally at an effort of 2.2 fish per rod-hour. Results of a creel-census conducted at both main locations showed that only an approximate 382 grayling were caught in 1965 in the Mackenzie River during the study, and about 452 grayling were caught in the Stark River in 1965 and 1966 during the study. Angling pressure on grayling was very light in Great Slave Lake. At present there does not seem to be a need for a change in the existing regulations concerning angling for grayling. A follow-up study is recommended to determine if any important changes have occurred since this present study. Recommendations are also made for a winter study on the grayling in Great Slave Lake. It is suggested that lodge owners be asked to keep records of the number and species of fish caught. It is thought that the spawning sites of grayling should be protected against illegal fishing methods during the spawning run.

11. Taxonomic measurements of 20 males and 20 females from each main location were carried out. Results of meristic and body dimension measurements were plotted

on log-log graph paper. They showed that there are significant sexual differences in the length of the pelvic fin and in the dorsal fin height. Significant differences were found in five body proportion characters between the East and West grayling: anal fin length, dorsal fin height, dorsal fin base, caudal peduncle depth, and anal fin base.

IX. LITERATURE CITED

Andrews, R. 1961. Creel census and population sampling of the sport fishes in the Cook Inlet and Bristol Bay drainages. Alaska Dept. of Fish and Game. Annual Report of Progress 1960-1961. Sport Fish Investigations of Alaska. Sport Fish Division. Vol. 2. pp. 115-152.

Brown, C. J. D. 1938a. The feeding habits of the Montana grayling, (Thymallus thymallus). J. Wildl. Mgmt. 2(3):135-145.

__________ 1938b. Observations on the life-history and breeding habits of the Montana grayling. Copeia. 3:123-136.

__________ 1943. Age and growth of Montana grayling. J. Wildl. Mgmt. 7(4):353-364.

Creaser, C. W. and E. P. Creaser. 1935. The grayling in Michigan. Pap. Mich. Acad. Sci., Arts and Letters. 20(1934):599-608. (Not seen).

Fabricius, Eric and Karl-Jacob Gustafson. 1955. Observations on the spawning behaviour of the grayling Thymallus thymallus (L). Inst. Freshwater Res., Drottningholm. Rept. No. 36. pp. 75-103.

Gustafson, K. J. 1948. Movement and growth of grayling. Inst. of Freshwater Research, Drottningholm. Rept. 29. pp. 35-44.

Hartman, G. F. 1958. Mouth size and food size in young rainbow trout, Salmo gairdneri. Copeia. 3:233-234.

Heckart, L. 1965. Inventory and cataloging of the sports fish and sport fish waters in the interior of Alaska. Alaska Dept. of Fish and Game. Annual Report of Progress, 1964-1965. Sport Fish Investigations of Alaska. Sport Fish Division. 6:291-305.

Hey, D. 1947. The fertility of brown trout eggs at the Junkershock Island Fish Hatchery. Trans. Amer. Fish. Soc. 77:65-80.

Hubbs, C. L. and K. F. Lagler. 1947. Fishes of the Great Lakes Region. Ann Arbor, Mich. pp. 19-27.

Ide, F. P. 1942. Availability of aquatic insects as food of the speckled trout, Salvelinus fontinalis. Trans. 7th North American Wildl. Conf. 1942. pp. 442-450.

Keleher, J. J. 1961. Comparison of largest Great Slave Lake fish with North American records. J. Fish. Res. Bd. Canada. 18(3):417-421.

__________ and B. E. Meeker. 1962. Results of a preliminary survey of the Great Slave Lake sport fishery. Fish. Res. Bd. Canada. M.S. Report. (Biol.) No. 725. 63 pp.

__________ 1964. Manual for Great Slave Lake field personnel. M. S. 66 pp.

__________ 1966. A survey of Great Slave Lake fishing. North, Vol. XIII(1):50-53.

Kennedy, W. A. 1954. Growth, maturity and mortality in the relatively unexploited lake trout, Cristivomer namaycush, of Great Slave Lake. J. Fish. Res. Bd. Canada. 11(6): 827-852.

Kruse, T. E. 1959. Grayling of Grebe Lake, Yellowstone National Park, Wyoming. U.S. Fish and Wildlife Service, Fish. Bull. 149:307-351.

Larkin, P. A. 1948. Pontoporeia and Mysis in Athabaska, Great Bear and Great Slave Lakes. Bull. Fish. Res. Bd. Canada. LXXXVIII(1948):1-33.

Leonard, J. W. 1939. Feeding habits of the Montana grayling (Thymallus montanus Milner), in Ford Lake, Michigan. Trans. Am. Fish. Soc. 68:188-195.

Micklus, R. C. 1961. A report on Minnesota's first grayling season, Twin Lake, Lake County, September 21-29, 1957. Minnesota Fish and Game Investigations. Fish series No. 3. pp. 63-68.

Miller, R. B. 1946. Notes on the Arctic grayling, Thymallus signifer Richardson, from Great Bear Lake. Copeia. 4:227-236.

Nelson, P. 1943. Life history and management of the American grayling (Thymallus signifer tricolor), in Montana. J. Wildl. Mgmt. 18(3):324-342.

Norden, C. R. 1959. Comparative morphology of certain salmonid fishes; with particular reference to the grayling (Thymallus arcticus), and its phylogeny. Univ. Mich., Ph.D. thesis, Zoology. pp. 214 (Not seen).

Norlin, A. 1967. Terrestrial insects in lake surfaces. Their availability and importance as fish food. Inst. Freshwater Res., Drottningholm. Rept. No. 47. pp. 39-55.

Rawson, D. S. 1949. Estimating the fish production of Great Slave Lake. Trans. Amer. Fish. Soc. 77(1947):81-92.

__________ 1950a. The physical limnology of Great Slave Lake. J. Fish. Res. Bd. Canada. 8:1-66.

Rawson, D. S. 1950b. The grayling (Thymallus signifer) in northern Saskatchewan. Can. Fish. Cult. 6:1-8.

__________ 1951. Studies of the fish of Great Slave Lake. J. Fish. Res. Bd. Canada. 8:207-240.

__________ 1953. The bottom fauna of Great Slave Lake. Ibid. 10:486-520.

__________ 1956. The net plankton of Great Slave Lake. Ibid. 13:53-127.

Reed, R. J. 1961. Investigations of the Tanana River grayling fisheries. Alaska Dept. of Fish and Game. Annual Report of Progress, 1960-1961. Sport Fish Div. pp. 215-224.

__________ 1964. Life history and migration patterns of Arctic grayling Thymallus arcticus (Pallas) in the Tanana River drainage of Alaska. Res. Rept. No. 2. Alaska Dept. of Fish and Game. 30 pp.

Schallock, E. 1965. Investigations of the Tanana River grayling fisheries: Migratory study. Alaska Dept. of Fish and Game. Annual Report of Progress, 1964-1965. Sport Fish Investigations of Alaska. Sport Fish Div. 6:307-319.

__________ [no date] Investigations dealing with probable grayling movement in relationship to water development projects. Unpublished manuscript.

Stroud, R. H. 1964. Endangered species program. Remarks given at National Conference on Conservation Issues, Wash. D. C. Dec. 10, 1964. M. S. report.

Tryon, C. A. 1947. The Montana grayling. Prog. Fish. Cult. 9(3):136-142.

Vincent, R. E. 1963. Biogeographical and ecological factors contributing to the decline of Arctic grayling, Thymallus arcticus Pallas, in Michigan and Montana. Univ. Mich., Ph.D. thesis. 1962. 169 pp.

Walters, V. 1955. Fishes of western Arctic America and eastern Arctic Siberia. Taxonomy and zoogeography. Bull. Amer. Mus. Nat. Hist. 106(5):255-368.

Ward, J. C. 1951. The biology of the Arctic grayling in the southern Athabaska drainage. Unpub. M.A. thesis. Univ. Alta., Dept. of Zoology. 71 pp.

Watling, H. and C. J. D. Brown. 1955. The embryological development of the American grayling (Thymallus signifer tricolor) from fertilization to hatching. Trans. Am. Micro. Soc. 74(1);85-93.

Wojcik, F. J. 1955. Life history and management of the grayling in interior Alaska. Unpub. M.S. thesis. Univ. Alta. 54 pp.

X. APPENDICES

A. Species list and locations of fish caught in Great Slave Lake.

Catostomus catostomus (longnose sucker)	Kakisa River, Mackenzie River, Stark Lake, Great Slave Lake (East)
Catostomus commersoni (white sucker)	Mackenzie River, Stark Lake
Coregonus clupeaformis (lake whitefish)	Mackenzie River, Stark Lake, Snowdrift River, Great Slave Lake (East)
Coregonus spp. (cisco)	Mackenzie River, Stark River, Stark Lake, Great Slave Lake (East)
Cottus cognatus (slimy sculpin)	Mackenzie River, Stark River
Couesius plumbeus (lake chub)	Snowdrift River
Esox lucius (northern pike)	Mackenzie River, Providence Creek, Kakisa River, Stark Lake, Snowdrift River, Great Slave Lake (East)
Lota lota (burbot)	Mackenzie River, Stark Lake, Great Slave Lake (East)
Prosopium cylindraceum (menominee)	Mackenzie River, Stark Lake, Great Slave Lake (East)
Pungitius pungitius (ninespine stickleback)	Mackenzie River, Stark River, Stark Lake
Salvelinus namaycush (lake trout)	Mackenzie River, Stark River, Stark Lake, Great Slave Lake (East)
Stizostedion vitreum (walleye)	Mackenzie River, Kakisa River
Thymallus arcticus (Arctic grayling)	Mackenzie River, Stark River, Snowdrift River, Kakisa River, Stark Lake, Great Slave Lake (East)
Lampetra japonica	Mackenzie River

B. Detailed list of organisms found in stomachs of grayling in Great Slave Lake.

Nematomorpha	
Gordius sp.	Mackenzie River, Stark River
Bryozoa	
Cristatella mucedo Cuvier	Stark River
Crustacea	
Cladocera	
F. Chydoridae (*Alona affinis*?)	Providence Creek
Amphipoda	
Pontoporeria affinis (Lindstrom)	Great Slave Lake (East)
Hyallela azteca (Saussure)	Providence Creek
Gammarus lacustris Sars	Kakisa River, Great Slave Lake (East)
Mysidacea	
Mysis oculta var. *relicta* (Loven)	Stark River
Insecta	
Ephemeroptera	
Ephemerella sp.	Mackenzie River
Ephemera simulans Walker	Mackenzie River
Odonata	
Ophiogomphus sp.	Kakisa River
Aeshna sp.	Kakisa River
Plecoptera	
Pteronarcys (*dorsatum*?)	Mackenzie River
Isoperla sp.	Mackenzie River, Stark River
Isogenus sp.	Mackenzie River
Capnia sp.	Kakisa River
Hemiptera (identified by Mr. D. Rosenberg, University of Alberta)	
F. Corixidae	
Callicorixa alaskensis Hungerford	Stark River, Kakisa River, Mackenzie River, Stark Lake
Arctocorixa chanceae Hungerford	Stark Lake, Stark River
Callicorixa audeni Hungerford	Stark Lake
Cymatia americana Hussey	Kakisa River

Hemiptera	
<u>Sigara decoratella</u> (Hungerford)	Kakisa River
<u>Hesperocorixa atopodonta</u> (Hungerford)	Kakisa River
<u>Hesperocorixa michiganensis</u> (Hungerford)	Kakisa River
<u>Sigara trilineata</u> (Prov.)	Kakisa River
<u>Cenocorixa dakotensis</u> (Hungerford)	Kakisa River
<u>Sigara fallenoidea</u> (Hungerford)	Kakisa River
<u>Sigara conocephala</u> (Hungerford)	Kakisa River
Trichoptera (identified by Mr. A. Nimmo, University of Alberta)	
<u>Brachycentrus</u> sp.	Mackenzie River
<u>Athripsodes</u> sp.	Mackenzie River
<u>Polycentropus</u> sp.	Mackenzie River
<u>Agrypnia straminea</u> Hagen	Mackenzie River, Stark River
<u>Apatania crymophila</u> (McLachlan)	Mackenzie River, Stark River
<u>Hydropsyche recurvata</u> (Banks)	Mackenzie River
<u>Phryganea cinerea</u> (Walker)	Stark River
<u>Anabolia bimaculata</u> (Walker)	Stark River
<u>Limnephilus</u> sp.	Mackenzie River, Stark River
Arachnida (identified by Mr. R. Leech, University of Alberta)	
<u>Tetragnatha</u> sp.	Stark River
<u>Philodromus</u> sp.	Stark River
<u>Sergiolus</u> sp.	Kakisa River
<u>Pardosa</u> sp.	Kakisa River
<u>Dolomedes</u> sp.	Kakisa River
<u>Metaphidippus canadensis</u> (Banks)	Stark River
<u>Paraphidippus marginatus</u> (Walck)	Kakisa River
<u>Sitticus palustris</u> (Peck)	Kakisa River
<u>Araneus cornutus</u> (Clerck)	Mackenzie River
Mollusca	
<u>Physa</u> sp.	Stark River
<u>Gyraulus</u> sp.	Stark River
<u>Lymnea</u> sp.	Stark River

C. Lengths, weights, ages and numbers of grayling caught by angling and gill netting in Great Slave Lake.

			Length (mm)		Weight (oz)		Age (yrs)	
Class	Gear	Number	Mean	S.D.	Mean	S.D.	Mean	S.D.
East	1	816	337.0	67.4	17.8	8.9	5.2	2.0
West	1	841	389.4	73.6	28.4	11.6	6.5	2.3
Total	1	1657	363.6	75.3	23.2	11.7	5.8	2.3
East	2	27	319.6	52.9	14.2	9.0	5.1	1.6
West	2	0	000.0	00.0	00.0	0.0	0.0	0.0
Total	2	27	319.6	52.9	14.2	9.0	5.1	1.6
East	3	231	383.8	50.0	23.9	8.3	6.9	2.0
West	3	6	412.7	50.2	28.7	7.6	8.2	2.1
Total	3	237	384.5	50.2	24.0	8.3	6.9	2.0
East	4	193	418.9	33.4	30.7	6.8	8.3	1.8
West	4	71	438.2	27.3	36.6	6.2	7.9	1.3
Total	4	264	424.1	33.0	32.3	7.1	8.2	1.7
East	5	44	436.9	36.7	34.9	7.2	9.0	1.7
West	5	194	425.5	29.2	34.0	5.8	7.8	1.1
Total	5	238	427.6	31.0	34.2	6.1	8.0	1.3
East	6	495	389.7	51.1	27.0	9.1	7.5	2.1
West	6	271	428.8	29.9	34.6	6.1	7.9	1.2
Total	6	766	409.5	46.9	29.7	8.9	7.6	1.8
East	7	1311	360.3	68.6	21.0	10.0	6.1	2.3
West	7	1112	399.2	67.7	29.9	10.9	6.8	2.2
Total	7	2423	378.2	70.9	25.3	11.3	6.4	2.3

Legend: 1 - angling; 2 - gill net (2 1/2 inch mesh);
3 - gill net (3"); 4 - gill net (4");
5 - gill net (5"); 6 - gill net total;
7 - total.

MACKENZIE RIVER GRAYLING (MALES)

FL	SL	LLS	GR	HL	HD	E	SN	IO	Max	SO	BD	CPL	CPD	DR	DH	DB	AR	AL	AB	P_1L	P_2L	P_1P_2	P_2A
450	413	90	6 - 13	83	65	21	18	27	32	57	106	58	33	20	125	129	11	51	53	71	73	137	103
397	361	87	6 - 11	73	60	20	18	24	27	51	97	55	32	21	94	110	13	46	44	56	65	117	95
423	396	82	6 - 12	82	61	21	21	27	32	60	99	58	36	24	129	127	13	50	50	62	70	125	114
435	397	83	7 - 13	81	59	21	20	28	30	59	94	57	35	21	133	125	13	48	50	74	83	122	111
395	363	92	5 - 13	73	60	20	19	24	28	53	91	54	32	19	101	110	13	44	45	66	69	113	96
438	398	81	7 - 13	82	65	22	21	28	33	58	98	58	36	23	145	135	13	46	53	80	99	102	105
368	337	90	7 - 11	71	50	18	19	23	27	49	86	51	32	21	86	102	13	38	43	59	66	105	93
461	426	91	6 - 13	88	66	22	22	28	31	61	101	59	39	21	109	135	13	47	50	73	90	122	114
435	398	90	6 - 12	83	68	20	20	26	30	58	98	55	38	21	117	122	13	43	52	75	81	122	120
398	357	88	5 - 11	72	55	20	18	22	27	52	87	53	31	20	112	92	13	45	46	68	76	117	105
423	390	87	7 - 13	78	60	21	20	25	31	56	95	51	34	23	116	131	13	51	55	78	84	119	105
391	354	86	6 - 13	72	56	19	17	24	27	49	90	55	32	22	87	111	13	43	44	67	70	114	100
361	332	93	5 - 12	65	48	19	15	21	24	49	78	49	30	22	80	98	12	37	44	63	66	107	89
397	365	87	7 - 13	76	56	20	18	24	29	55	87	55	33	22	127	112	14	44	49	70	76	112	94
368	337	88	6 - 12	66	56	18	15	21	24	47	80	50	31	21	75	100	13	39	41	54	56	105	93
431	392	87	7 - 12	83	64	21	21	25	32	61	96	58	34	22	133	133	14	47	56	74	36	121	112
480	439	89	6 - 14	91	66	22	24	31	36	64	105	58	38	24	154	147	14	50	55	80	90	136	111
433	400	80	7 - 13	85	62	21	20	28	32	60	97	57	37	22	156	134	12	51	50	82	90	124	97
434	450	83	6 - 12	87	68	22	21	29	32	62	105	67	38	24	147	146	13	53	58	80	95	153	112
413	377	91	6 - 14	73	56	20	17	21	28	53	91	58	32	24	96	124	13	33	47	57	70	120	114

MACKENZIE RIVER GRAYLING (FEMALES)

FL	SL	LLS	GR	HL	HD	E	SN	IO	Max	SO	BD	CPL	CPD	DR	DH	DB	AR	AL	AB	P_1L	P_2L	P_1P_2	P_2A
405	371	87	6 - 12	74	55	21	18	25	26	53	85	47	32	23	82	115	12	45	43	64	64	113	110
470	429	83	6 - 9	93	65	22	22	27	32	59	101	60	37	22	104	123	12	54	52	75	72	137	121
447	410	83	7 - 12	80	66	22	18	25	29	58	104	63	37	22	97	129	12	54	51	67	68	132	113
462	423	92	8 - 12	82	59	23	20	27	31	60	97	61	35	21	117	126	12	54	50	72	76	134	118
425	391	90	6 - 11	76	61	22	19	25	29	58	95	56	33	22	94	114	13	47	48	67	69	118	113
437	396	93	6 - 11	80	63	21	20	25	31	55	95	58	35	24	103	131	13	52	49	64	70	130	111
404	368	98	6 - 14	75	60	20	19	23	28	54	98	51	34	22	82	114	13	46	43	64	70	125	106
427	390	87	6 - 12	85	62	21	20	26	30	57	100	53	35	23	99	118	13	48	45	72	72	119	112
515	375	89	6 - 11	70	60	19	18	24	25	50	95	56	35	21	73	116	11	45	44	63	63	113	109
458	421	84	6 - 14	83	66	21	20	26	30	61	100	63	33	21	83	121	13	45	46	65	69	139	125
415	377	83	6 - 12	74	59	21	18	24	30	54	98	57	33	21	103	105	11	45	46	71	73	115	106
419	382	87	7 - 13	80	62	21	19	25	30	58	95	55	34	23	94	124	12	46	48	72	73	123	106
428	392	91	7 - 13	76	57	20	18	23	27	54	98	60	34	23	90	123	13	45	43	64	71	121	116
360	330	89	4 - 12	68	51	19	17	21	26	49	83	47	30	20	76	98	12	43	37	63	67	106	93
418	392	93	7 - 14	76	55	20	18	22	29	55	88	59	35	22	95	120	12	43	48	65	70	123	116
371	343	87	7 - 14	70	52	19	17	21	25	49	87	50	31	23	69	104	13	39	39	66	65	103	96
398	361	85	6 - 13	75	55	19	17	24	29	53	92	56	33	21	74	110	13	43	44	68	68	117	106
378	345	92	5 - 11	69	53	19	17	20	26	50	86	53	31	21	83	106	13	36	43	66	66	107	99
419	384	91	7 - 13	75	56	19	17	23	26	51	89	62	34	22	90	106	13	46	43	64	65	119	109
424	392	81	6 - 12	81	56	19	18	25	28	54	92	59	35	23	90	121	13	48	47	74	76	119	105

STARK RIVER GRAYLING (MALES)

FL	SL	LLS	GR	HL	HD	E	SN	IO	Max	SO	BD	CPL	CPD	DR	DH	DB	AR	AL	AB	P_1L	P_2L	P_1P_2	P_2A
417	333	92	6 - 10	73	57	21	18	23	23	55	88	59	34	20	103	99	12	44	43	67	71	127	101
435	403	93	6 - 12	87	72	21	23	27	35	62	99	64	34	20	110	128	13	46	47	71	81	122	115
404	375	92	6 - 13	70	59	19	18	23	26	51	91	60	31	19	87	85	14	38	42	58	68	119	106
444	403	95	5 - 13	82	69	22	23	26	34	62	99	58	36	22	133	115	12	44	43	72	81	137	113
446	412	95	6 - 11	85	60	22	23	27	33	57	95	57	34	21	112	122	12	42	52	70	90	131	117
381	348	92	5 - 12	70	52	19	19	23	26	48	83	54	30	20	81	95	12	39	38	57	59	111	104
393	361	85	6 - 11	72	59	18	13	23	27	50	91	55	30	22	85	103	12	42	44	60	65	112	105
450	411	92	6 - 14	87	66	23	21	30	35	63	98	63	34	19	115	121	12	46	47	73	82	132	114
404	374	95	6 - 13	74	53	21	13	22	28	55	90	55	30	20	93	106	11	46	45	69	77	120	97
340	310	83	7 - 12	63	51	18	15	21	23	48	80	45	23	21	60	87	11	35	32	52	58	99	92
383	350	85	5 - 13	71	51	20	13	23	27	51	85	55	29	21	84	95	12	40	37	62	65	107	98
451	417	92	7 - 12	85	65	22	22	27	33	60	95	65	32	18	134	108	12	36	45	79	83	123	117
441	408	91	6 - 13	82	61	22	22	23	32	59	95	60	34	21	136	127	13	40	47	74	79	123	107
355	322	90	6 - 13	64	49	17	17	22	24	43	80	50	27	20	64	90	13	33	38	55	61	102	91
474	443	87	6 - 15	86	66	22	22	25	35	62	95	73	35	22	128	122	12	42	50	72	84	137	124
474	438	93	7 - 13	85	67	22	21	29	35	61	99	63	33	21	111	124	14	39	59	75	83	132	124
365	342	83	6 - 13	67	48	13	16	19	25	49	79	52	30	21	77	91	11	33	36	62	64	111	92
367	340	89	6 - 11	56	48	19	17	20	28	51	84	56	29	21	78	87	11	37	34	63	65	108	96
433	403	85	6 - 13	79	58	20	21	23	32	55	83	60	32	20	115	108	11	39	44	70	79	126	117
420	387	88	6 - 12	74	59	20	18	23	30	58	81	57	32	20	101	108	12	41	45	69	77	123	100

STARK RIVER GRAYLING (FEMALES)

FL	SL	LLS	GR	HL	HD	E	SN	IO	Max	SO	BD	CPL	CPD	DR	DH	DB	AR	AL	AB	P_1L	P_2L	P_1P_2	P_2A
441	404	97	6 - 13	81	61	21	20	26	32	59	91	56	31	20	60	106	12	41	45	65	63	135	117
422	390	92	6 - 14	81	62	21	21	26	29	53	95	55	34	21	89	100	13	44	43	53	72	124	113
425	337	90	5 - 10	73	60	20	20	24	39	57	95	56	32	23	30	110	13	49	41	63	68	116	100
415	379	89	6 - 13	80	63	21	21	25	31	56	96	61	34	19	72	95	11	42	33	58	62	121	100
403	371	94	5 - 13	73	53	20	18	24	26	51	88	60	31	19	73	99	11	40	40	60	63	112	107
429	391	87	5 - 11	82	59	22	22	25	32	57	96	60	32	24	94	115	14	47	44	69	71	120	106
407	377	97	6 - 13	76	55	20	19	24	29	53	91	60	32	22	36	95	13	47	45	62	61	120	111
393	365	90	4 - 11	75	60	20	20	23	29	53	95	57	32	21	89	93	12	45	40	62	72	126	106
430	376	94	6 - 12	81	57	22	19	27	31	57	91	55	34	21	30	104	13	43	46	79	76	115	109
358	327	93	6 - 12	64	51	17	15	20	24	49	84	56	27	19	49	88	12	35	37	56	53	105	93
428	396	94	6 - 12	78	60	22	20	26	30	57	87	61	23	20	33	104	11	48	41	72	74	116	123
381	348	89	7 - 13	70	53	18	17	21	26	53	79	55	30	20	55	91	11	39	37	68	69	108	101
441	403	93	6 - 13	84	60	21	20	27	31	58	96	62	32	22	37	113	12	48	47	70	78	127	115
380	351	91	5 - 13	71	52	19	17	21	26	51	78	55	29	19	82	99	13	42	33	63	60	106	94
438	399	91	6 - 12	79	63	21	19	26	30	55	93	58	34	19	30	111	12	46	44	70	77	126	109
352	323	89	6 - 12	65	49	17	15	22	24	47	80	52	29	21	62	92	11	36	33	56	58	99	86
402	372	85	6 - 13	71	47	18	17	22	26	46	81	58	29	21	77	104	14	36	35	66	71	121	109
384	355	92	7 - 11	71	56	18	17	20	27	51	75	55	30	19	64	92	12	40	40	59	59	116	102
391	361	94	6 - 13	70	54	18	17	20	28	51	76	52	29	22	54	102	12	39	39	63	62	116	99
375	342	88	7 - 13	67	54	18	16	21	24	50	75	54	29	21	58	87	12	41	36	59	58	113	89